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# University Studies

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## I.—*The Kinetic Theory of Economic Crises*


BY W. G. LANGWORTHY TAYLOR


### I

### THE KINETIC THEORY OF ECONOMIC LOGIC

The theory that there is somehow or other such a sympathy between the different phases of social life that they all bear the same hall-mark at any particular epoch, and that a common change takes place in all of them from one epoch to another, is so fascinating as to form the more or less unconscious assumption of much of our reasoning about society. Even if it be impossible to show that this sympathetic movement occurs precisely at the same moment in all phases, it may still be most plausibly assumed that a given impulse is propagated from one phase of life to another so that all may share in the common movement within a reasonably close period, although at any given moment there will be some that are through with it and others that it has not yet reached.

Just what this is that can be common to so many and so different elements we need not attempt to describe. We characterize many social phenomena as belonging to the savage, barbarous, civilized epochs. While we may err in cataloguing our items into this or that epoch, we assume confidently our use of stages and epochs. We assume, further, that this succession of general stages constitutes a progress, although we do not often


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venture to hint in what it is that progress essentially consists. This paper is no exception to the general tendency to make these assumptions.

The present age is characterized by some sociologists[1] as the economic-ethical. It has left in the rear the ponderous debate on constitutionality, the closet speculations of metaphysics, and the bloody contests of religious schism—all stages of activity that were doubtless necessary, but could hardly be looked upon as rapid means of solving the problems of life. In the economic-ethical age, we find less casuistry and greater definiteness. The discussions of previous ages have rendered many distinctions simple that then seemed novel and fine-spun. With such a foundation laid, there seems room for unlimited activity. The manifold phenomena of life are no longer confounded, and hence a vastly greater number of separate paths are opened. These paths soon have tracks laid upon them, and instead of walking we find ourselves carried at railroad speed. In some such way it is that the present age is characterized as one of motion.

The new philosophy finds the end and well-being of man as of Nature, in energy. Function is more important than structure. In the public eye it is doing, not wealth or rank, that occupies the foreground. The man of action wins admiration. The doctrine of the *strenuous life* is undoubtedly extremely popular and may even turn the balance in favor of a political candidate against the preferences of the party machine and of the party boss. Hence, progress is the watchword and keynote of the day. In science and in education, those closely allied phases of life, we must expect to find it, and we shall be lacking in our assumed duty of harmonizing ourselves with the spirit of the age if we do not seek to work out its principles. The task in hand, therefore, is that of analysis of life rather than of living itself. We seek to understand and to explain.

The close connection of science with education causes them mutually to affect each other. The methods of science must depend to a certain extent upon those of education. It is in the field of education that we come most closely in contact with the

[1]Cf. Professor F. H. Giddings, *The Principles of Sociology*, p. 302.

processes of the human mind. The scientific investigator uses—without full self-consciousness—the tools given him by Nature, much as any other reasoner does. In so far as he is unconscious of his process of thought, he may be set down as a really living man (on a psychic plane, however), although he is engaged in the investigation of the actions of those who are in a more material sense living men. In order that he may reach a high self-consciousness, he must be brought in touch with the problems of education, for these are essentially the problems of self-consciousness. It is said that President Eliot conceives the true end of education to be to secure "effective power in action."[1] While this definition is doubtless correct from the point of view of a college president who wishes to impart every desirable epoch-making quality to his students, and while it is strictly in line with the spirit of the age, the question may be raised whether it is not technically too broad. The distinctive feature of education, narrowly viewed, and especially in the present epoch, is the attempt to make the student acquainted with facts and with accepted forms of thought, and to make him acquire a sort of self-consciousness about them. The object is to acquaint him with facts of a higher order, those which he is not likely to acquire in the push of life. These consist largely in general propositions and may be treated not only as scientific facts but as indications of the methods of thought employed in the several sciences and for instruction in them. Some facts of a lower order are also necessarily inculcated because they are the means of acquiring the higher kind of facts and can not be learned in ordinary experience; such, for example, are the languages when regarded merely as work tools, and the use of laboratory instruments in the various natural sciences. Our business is to discover what kind of thought and facts is characteristic of the present age of material progress, adequate to investigate it and to describe it, and suited to the apprehension of the students likely to be encountered. We take the liberty of assuming, then, that the method of investigation and the method of teaching are to be in harmony with the progressive spirit of the age: investigation must have for its

[1] G. P. Morris, *President Eliot of Harvard*. Review of Reviews, March, 1902.

object the essential facts and laws of progress, while education must recognize how persons of different epochs and at different ages are able to apprehend them.

Education assumes that the mind is immature, whatever may be true of the body. There is much truth in the observation that the individual must in his early personal experiences pass through the history of the race. He is the microcosm, and from nebulous beginning must in a short time develop into a representative of the most highly differentiated organism. When fully matured he will be master of the methods of thought prevailing in the epoch. In the course of his development, however, the methods of earlier epochs are applicable. To the child, all phenomena are present. There is but one reality—the present. He conceives of everything he observes as eternally the same. His method is arithmetical, logical, and static. To the man, the world is an old story. Nothing surprises him. Wonders have ceased. He amuses himself by watching the fleeting panorama of life. His observations are of rate of progress and of changes in rate. He notes recurrences of high and low speed. His method is organic and kinetic; his economics is "a calculus of pleasure and of pain"[1] (Jevons).

Now we avail ourselves of the distinction between science and education. The professor in his study is analyzing the tendencies of the times; in the class room he is adapting his instruction to minds of earlier epochs. A description, then, of present methods of thought in the social sciences would be impossible without the contrast afforded by former methods and without noting the imperceptible transition from the old to the new—a comparison which is to be made chiefly in the field of educational method. What was and is the static thought with which we are to contrast the newer kinetic thought? It must have been, of course, a statement of reality as apprehended by the past investigator and as imparted in the present class room. At this point the doctrine of the harmonious development of different social phases receives unexpected confirmation. That is only real which is apprehended as such. Higher realities are only potential

[1] If not of pleasure and pain, anyhow a calculus.

to the development of our faculties. The action and reaction between science and education would naturally keep them in touch with each other and with the spirit of the age in this matter of reality. The living world may progress all unperceived. The potential environments which it is entering and which it is realizing in life are unreal and non-existent to men's apprehensions. The truth as it is perceived is not the truth as it would be perceived by more advanced beings. Therefore the truth as we know it can be of no higher order than our method of thought allows; and the nature of this method is most clearly apprehended in the field of education.

In view of the relativity of social and economic laws, as above explained, let us now turn to the characteristics of static and kinetic thought, respectively. The most prominent characteristic of static thought is that it clings closely to the simplest logic of premise and conclusion. In its endeavor to reach conclusions of the utmost clearness and simplicity, it assumes the whole environment, with the exception of one item, to be unchanging. If the environment is one naturally in motion, it is assumed that the rate of motion is not changing, or if the rate be changing, it is assumed that the rate at which the rate is changing is itself unchanged. In other words, it contemplates any given state of affairs as static with relation to one factor which is selected out for *differentiation*. The effect produced by this variation is a *logical conclusion,* and, if sufficiently authentic and general, may constitute a static law.

Now, it is not claimed that we can ever disembarrass ourselves completely of this method of reasoning. Still, we can recognize its weakness and hope that an age of men is arising that is able to reason better. The simplicity of this form of thought is due to the simplicity of mind to which it is adapted. It is a safe proposition that with more complex minds we shall be able to vary more than one item at once, or so nearly simultaneously as to produce a nearly simultaneous effect. In a static age, men acted on simple motives. Life was assumed to be simpler than it is now assumed to be, and simple conclusions were reached. Progress was hindered, however, by the fact that the conclusions were too

simple. As already noted, it is the fine distinctions that prevent interference and allow rapid progress. It was supposed in the static age that men used logic as a ground of action; that men acted upon conclusions drawn from premises. At present we see that men adapt themselves to their environment by an organic process and that reason is rather an effort to understand the environment and to complete the adaptation than the invention of proper motives to action. The modern point of view, therefore, does not connect reason with action so closely: it is less intensely personal, and leaves the mind free for the apprehension of simultaneous variations in different items.

A statement of some of the hypotheses of John Stuart Mill's *Political Economy* will illustrate the nature of the assumptions of static thought:

1. Mill constantly accepts the popular conception of the wealth, of the capital, and even of the source of wages in society as constituting a definite fund. This conception has been found so unreal by later thinkers that it has been abandoned in systematic treatises. It exaggerates the importance of the conceptions of wealth and capital relatively to that of income, and when applied to wages, rent, and interest requires so much explanation and qualification that the fundamental idea of a fund is lost and hence comparatively useless. Nevertheless, for the youthful mind in the static epoch, it is probably the only method of creating a vivid self-consciousness on these economic topics.

2. Mill supposes in some cases that capital may be instantaneously withdrawn from one industry and invested in another without loss. In other cases, he supposes that capital is a fixed amount, for example, when he treats of the injury done to laborers by the adoption of machinery.

3. He supposes labor and capital to act purely from selfish motives.

4. In his desire to reach fundamental principles, he considers in many cases ultimate effects to the exclusion of immediate effects; but sometimes he pursues a contrary course.

5. He speaks frequently in his masterly treatment of international trade, of absolute wages and profits, as if any wages and profits did not need to be accounted for.

6. Like Ricardo, he compels the reader to make difficult assumptions as to "other things being equal."

The above criticisms of Mill are not offered in an adverse spirit. On the contrary, it is maintained that the static method of thought is necessary at some stage in the development of a society, of an individual, and of the investigation of any given social phenomenon. It is nevertheless manifest that the higher truth consists in the apprehension of things as they move, live, grow, and act. The rapid movement of modern life necessitates increased rapidity of movement of the modern scientific mind engaged upon social problems. When progress was slow the method of noticing single variations seemed satisfactory; the student did not realize its inadequacy; he did not feel as though his labor was lost through the rapid change of environment. The environment apparently was the same when he had concluded his investigation that it was when he began it. Not so with the modern student: he feels that the environment that he begins with is slipping away in the very course of the investigation of one of its parts.

While we are casting about for a new method of investigation, it would not be surprising if the subject-matter itself changed. New methods, new subjects. It is now the change in the environment itself, whether capitalistic, squirearchal, or what not, rather than its details, such as wages, rent, and interest, that attracts our attention. The changes of detail are looked upon as flowing from the change in environment. This change of subject-matter comes in to relieve somewhat the strain of the kinetic process, for we may treat the social change as a whole and so retain something of that simplicity which constitutes the advantage of static thought. At the present moment, however, we are to inquire, not into the concessions that must be made to static thought even in a kinetic investigation, but as to the nature of the kinetic investigation itself.

The desideratum is a method of reasoning in which several elements may be allowed to vary at once so that we are not held down by the condition that but one factor may be changed at a time. We wish to hear no more of the cumbersome and glaring

unreality of a "fund." We wish to feel our whole being move with nature, to comprehend many motions at once, to follow many themes simultaneously. The problem of reasoning is the problem of clear ideas. The success of the static method lay in the fact that it isolated impressions so that they were clear. Evidently the requisite of distinct impressions at the self-conscious center[1] is inexorable. The problem, therefore, is that of satisfying the condition of motion without destroying the clearness of the mental picture. There is but one conceivable means by which this result can be accomplished, and that is so to train the mind that it may receive successive distinct impressions at shorter and shorter intervals, until finally, the distance between the impressions decreasing indefinitely, they blend together into one homogeneous picture. The simultaneous action of many different elements is thus portrayed. This picture will constitute a higher, a kinetic reality. Any student will recognize that in moments of most successful thought he experiences pictures of this sort. Even when we do not visualize environments as wholes in this way, it is common for a well-stored mind to suggest particular after particular with almost lightning rapidity until the whole conjuncture is reproduced.

The ability of the kinetic method to ease the mental strain by permitting the use of static thought through this rapid differentiation suggests that the old categories by which the economic situation was analyzed are not to disappear at once. Land, labor, and capital, rent, wages, and interest will abide with us still; but they will not maintain so prominent a place. They will belong to the lower rank of thought, retained in order to form a connecting link for the practical application in life of the higher realities. At the same time, new categories will be evolved in the social life. Discussion will turn about the more fundamental traits of human nature involved in progress. The effort to obtain clear ideas will be connected not so much with the newer as with the older categories. They will now seem complex, since a single variation in the newer will involve multiple variations in the older.

[1]The theory of brain mechanism here followed seems to offer a simple explanation. The writer does not wish to be understood as definitively committed to it.

Everywhere the conception of motion will be introduced, so that the self-conscious center will be called upon to visualize, at the same moment, successive positions in time and simultaneous positions of all the elements.

It is well to note in passing that the new method seems to favor the doctrine of individualism. Socialism (the older type, at least) is an attitude of mind essentially static. While it does look upon society primarily as a whole, it goes too far in treating it as independent of individual action and not as in action itself, but as capable of being moulded, like a sort of fund, into any conceivable, definitive shape. While individualism may well investigate society from the social point of view, it does so on the supposition that the general social situation is rather a mode of thought than an objective fact and is at any rate the result of individual efforts. Socialists have no need of kinetic thought since its adoption would be a confession that society is objective, complex, and not amenable to simple administrative regulations.

The common sense deliverances of normal men, especially about their own industries or businesses, are more kinetic than those of the student or teacher. They are in fact a part of the very process that is to be investigated. Common sense opinions as to social prosperity, or even as to national or local policy, are often more trustworthy than those of students and professors, for they are but a part of the general life. The distinction between them and the opinion of scholars is that they are less self-conscious. The task of the student is to reduce this instinctive thought to self-consciousness. He selects such sequences as may be clearly separated. The result is an obvious gain in clearness, but a relatively low reality. The situation thus devitalized is said to be "logical." Logical conclusions are obtained at the expense of comprehensiveness but to the advantage of clearness. They are partial and dangerous except in the hands of experts. How many a worthy teacher of political economy has allowed himself to be side-tracked into dogmatism about free trade or hard money because he had forgotten for the moment the artificial simplicity of the premises and thus allowed his static logic to obtain the mastery over his inexperienced motor nerves! On his tombstone

should be written this epitaph: "Slain by an Idea." How many of us are in bondage to ideas instead of using them as a means of daily upbuilding! Thus the search for clearness may actually lead us away from higher and down to lower realities. Are the difficulties inherent in clear thinking to prevent us forever from attaining to the highest realities? Whatever change takes place in our method, it can not afford definitively to sacrifice clearness. It makes little difference whether we say that we abandon the logical method or that we change our logic—that is a mere matter of words. The impact of the isolated stroke must not be lost. It is possible that the caliber of our guns has reached its limit. It is the rapid succession of distinct blows on which we are henceforth to rely. The self-conscious center will remain the target of the sensory fire. The question of the improvement of our logic is a question of the target's power of resistance and of the rapidity and exactness of the discriminating fire maintained by the subordinate centers. We have seen that the advantage of education consists in increasing our self-consciousness and that the method to this end is a logical one. We have also seen that logic suffers from the very considerable disadvantage of partiality and one-sidedness; it necessarily introduces us only to a portion of our subject; it separates out particular influences and traces them through an otherwise unanalyzed and unexplained mass of material. Not only does this process tend to destroy mental perspective, but it may even cause us to know practically less about the whole subject and its relation to life than we might otherwise have known from common everyday experience. This result is deeply to be deprecated. Of course, the static method, by repeated applications, does, after a fashion, bring about a pretty fair analysis of the subject-matter. Life is like a geometrical solid; it may be sliced by an infinite number of planes at an infinite number of angles in order to analyze it fully. But this process does not suit our rushing age. The aim of the newer logic must be "to bring theory and practice together," and this without unreasonable delay. We wish not merely to perceive the relation of all the parts of any given section to each other, but also to *feel* the motion of those parts incident to their rearrangement. Life

would better be compared to an elongated solid of which we wish to take an infinite number of cross sections and also longitudinal sections. Doubtless the old method of education in static logic is highly beneficial—but rather for the objective habit of mind and the scientific scepticism that it encourages than for any actual knowledge that it gives. If education can give completer knowledge than it has heretofore furnished it would undeniably be much more beneficial. The popular phrase "to bring theory and practice together" really represents the greatest scientific desideratum.

Learning is being democratized along with everything else. The student can not afford to assume aristocratic airs toward the practical man. The latter has a right to be proud of what he does; the former can only point to his thoughts and his ideals. To few of us is it granted both to think and to do or live. If the practical man—the man who really lives—knew how weak was the logical armor of the theorist, his scorn would be redoubled. The theorist must be prepared for the "I told you so" of the practical man. The former has lofty aims, incomprehensible to the latter; the latter judges all men by results upon his own materialistic plane—his own geometrical slice; his only standard is facts accomplished; his only facts are short-time and materialistic; with him there can be no dispute; his contention must be admitted as he understands it. It is not worth while to explain to him that there are things that he does not understand. He that scorns the schools and does not acquire high ideals in the school of life would better be left undisturbed. After all, the practical man is the material, the very stock in trade of the social student. Without the former the latter would have to go out of business. The experimental material for the social laboratory would be gone. Let our thought, however, become thoroughly kinetic, the crevice in the scientific armor will be repaired, and even the appearance of unpracticality will be saved.

Having considered in a general way the imperfections of the older logical method, more particularly with reference to the social sciences, and the general scope of what we may hope for from the future, we may now turn our attention to a short statement of what is being accomplished in the line of kinetic social thought.

A specific example of the old method will serve to give point by contrast. In his chapter "Of the competition of different countries in the same market," Mill shows that if a country be undersold it will simply reduce the general level of its prices and so enable itself to regain its former market; however, the falling off in foreign demand for a particular article may cause the production of it to be accompanied with loss: "The loss which the country will incur will not fall upon the exporters, but upon those who consume imported commodities; who, with money incomes reduced in amount, will have to pay the same or even an increased price for all things produced in foreign countries."[1] To the practical man the statement that exporters will not lose money in losing their market seems preposterous. Anyone knows that a business man loses money when he loses his market, as Professor Laughlin points out in his edition of Mill. What Mill really meant was that the business of exporting would continue just the same, but that the consumers of foreign goods would find no compensation for the fall in their own incomes and the rise in the price of foreign goods. Mill's mind was so fixed on a final and permanent state of affairs that the temporary losses of a few exporters did not seem to form a part of the proper subject of discussion. We could excuse this omission did not the static method of thought lead him into a graver error; for the consumers of imported commodities are left permanently consenting to pay a high price for foreign goods upon a small income. Now, of course, Mill's premise was that the country was undersold; therefore the results of underselling must last only so long as the cause lasts. We obtain a vivid picture of the possible ultimate effects of underselling, but only a very partial and one-sided view of the real course of foreign trade relations. Probably the balance of trade will turn in so short a time and to such an extent that the loss which the consumers of foreign goods suffer will be no greater than that which the producers or exporters of domestic goods will have suffered. Mill, however, by supposing the adjustment of the capital, prices, etc., of the exporters to be instantaneous, and by again supposing the losses of the consumers to be perma-

[1] *Principles of Political Economy*, bk. III, ch. 20, sec. 1.

nent, has produced upon the mind an effect of distorted perspective which is only too likely itself to be permanent.[1]

It would be idle to claim that the static logic, of which an example has just been given, could or should be dispensed with. An inspection of all static sections of the social material is a prerequisite to further economic investigation. The mind becomes trained in rapidly passing from section to section. A mind that has acquired this facility has attained to what we call *good judgment;* all the artificial static propositions are become so familiar to it that it does not object to move at an instant's notice in any direction on a reasonable suggestion, and is not conscious of any considerable resistance necessary to be overcome in order to reinspect one of the multitudinous sections. The prejudiced person refuses to adapt his thoughts to circumstances; the trained mind passing quickly from section to section obtains a pretty good general view and is enabled to correct one exaggeration by another. As already stated, this appears to be the mechanism of good judgment as exhibited by the ordinary trained thinker; it often enables him to silence the practical man in argument.

The purely kinetic method, on the other hand, will naturally seek new categories, and its use will evolve new theories. Some of the most kinetic effects, however, are produced by adherence to the old categories. Such adherence results in what may be called a partial or quasi-kinetic method. The best example perhaps is that of Professor Alfred Marshall in his *Principles of Economics,* and yet his treatment is so kinetic that it produces upon the mind as much of the satisfying effect of motion as those writers who have applied kinetic conceptions to newer categories.[2] The desired effect is produced by the systematic employment of the method of equilibria and differentials—a method that at once

[1]This statement is made in the full knowledge that Mill puts in a saving clause by supposing the country to be "temporarily" undersold.

[2]The question at issue between static and kinetic methods appears to be similar to the question whether political economy is an evolutionary science. Professor Veblen credits Professor Marshall with some evolutionary qualities, but hardly with sufficient, if we take into account bk. V, ch. II, secs. 4–6, and especially the concluding note. *The Preconceptions of Economic Science III*, Quar. Jour. of Economics, February, 1900, p. 262, sqq.

appeals to one as essentially evolutionary and kinetic. Every old category is vigorously submitted to this treatment, with the uniform result of a philosophical continuity between the categories, which are filled with life and action. The reader is made to *feel* at least as though he were cognizant of many motions taking place simultaneously, or at least in such quick succession that the self-conscious center is aware of but one continuous movement. This movement, then, being single, attains to the appearance of simplicity—the result desired for logical clearness—and if formulated would constitute a new economic law, so far as anything can be new that is composed of antecedent elements. But Marshall refrains from new names and formulas. He possesses thorough English conservatism, and prefers scientific evolution to mere literary effect or a loudly announced revolution. Since all invention is but a sufficient degree of rearrangement, we may grant to him the merit of an originality strongly stamped with the kinetic die. The following citation is typical:

"The production of everything, whether an agent of production or a commodity ready for immediate consumption, is carried forward up to that limit or margin at which there is equilibrium between the forces of demand and supply. The amount of the thing and its price, the amounts of the several factors or agents of production, used in making it, and their prices—all the elements mutually govern one another, and if an external cause should alter any one of them the effect of the disturbance extends to all the others.

"In the same way, when several balls are lying in a bowl, they mutually govern one another's position; and again, when a heavy weight is suspended by several elastic strings of different strength and lengths attached to different points in the ceiling, the equilibrium position of all the strings and the weight mutually govern one another. If any one of the strings that is already stretched is shortened, everything else will change its position, and the length and the tension of every other string will be altered also."[1]

[1]Marshall, *Principles of Economics*, 4th ed., bk. VI, ch. 2, par. 1.

The kinetic method is essentially at home in the field of progress and prosperity, and lends to it new significance. It is characteristic of this field, which the older economics recognized indeed; but the static tools at command did not lend themselves readily to the dimly foreshadowed problem. Those tools were better adapted to the old categories, were characteristically employed in them, and pretty closely confined the old economics to them. It is a great triumph for Professor Marshall to have introduced the newer method into them.

The very thought of progress (in itself an assumption, if you choose) implies motion. In dealing with it one must make allowance for speed, as when a cowboy circles the riata above the horns of a fleeing steer. The tool found, material can not long be lacking. A general shifting and renewal of categories takes place. The newer theories assume society as a whole to be in a state of motion. They then investigate the effect of this motion on the various categories. So far their method differs from the older chiefly in more systematically taking their start from the provisional conception of society as a whole.

The newness of the categories constitutes another and perhaps more salient difference. Instead of materialistic interest, wages, and land rent, we now have all economic phenomena reduced to psychological categories of pleasure and pain, cost, surplus, producers' and consumers' rents, the law of substitution, and the like. Space and time are regarded more abstractly and metaphysically. Well-being is thus dissociated from political, constitutional, or traditional classes, and identified with the simple economic elements of human nature.[1]

Other analyses, in retaining the old categories, expressly state that their reasoning is static, and hasten to admit that a full formulation of social action must comprise the distinct studies (1) of the separate laws of progress and (2) of the laws of the interaction of the kinetic laws of progress with the static laws of distribution.[2] Only when these latter studies are completed will that full picture be presented that will really bring theory

[1]E. g., Professor Simon N. Patten, *The Theory of Dynamic Economics.*
[2]Professor J. B. Clark, *The Distribution of Wealth*, ch. VII.

and practice together. The distinct admission of the limitations of static theory is one of the greatest services to science, and places such theory on stronger grounds and in a truer light. However, formulation is one thing and appreciation quite a different one. Because one student is capable of *feeling and experiencing* with clear consciousness the progressive process, passing the various social phenomena in triple ranks—static, kinetic, and stato-kinetic—before his mind with such rapidity and certainty that they produce but a single effect upon the self-conscious center, it does not follow that any one else will be able to visualize the same picture upon the suggestion of a written or oral description. The progress of science depends on our own progress after all.[1]

The result of our discussion is that there are habits of thought that may properly be characterized respectively as static and kinetic; that the latter does not wholly supersede the former but serves additional purposes; and that the former is still especially useful for education of the young and for exact thought of a not very advanced type. Perhaps the chief characteristic of static thought is its employment of contrasts. Ignoring the gradual changes presented by nature, it seeks to cause clear ideas by accumulation, as it were, of all the infinitesimal variations until a given point (a point of satiety perhaps) and by then discharging the accumulated suggestions like the shock of a Leyden jar upon the self-conscious center. This method is especially observable in the treatment the orthodox economics accorded to the assumed unhomogeneous and discontinuous categories, land, labor, and capital. While Professor Marshall has unquestionably succeeded in substituting continuities for these discontinuities, the art and the profundity of the achievement can hardly be appreciated by a reader that has not studied the older writers. In the study of progress, however, the older writers did not avail themselves of the method of contrasts, except by drawing inferences from their studies in distribution and exchange; and as they had no distinctively kinetic method, they were as badly off for exposition

[1]Professor Marshall touches the field of pure kinetic theory in various places, but especially bk. V, ch. II, sec. 6, note 1, p. 521.

as they were for investigation in this field. We, however, in adopting newer methods should not lose the advantages of the older. It will be most convenient, therefore, to assume in the first place that progress is not continuous, but that it is attained by a series of sudden springs or leaps, from one stage to another and higher. We shall then be able to assume that between the different leaps a period elapses, during which there is no change and in which the social phenomena bear a distinct hall-mark.[1] Thus we shall attain to a static clearness of thought through the contrasting of one assumed epoch with another.

Just as sociologists have characterized different periods of human history as military-religious, liberal-legal, and economic-ethical, so economists will give names to different stages of economic development, such as the landed stage, the capitalistic stage, the stage of transportation, the stage of combination and organization, etc. The first duty after agreeing upon the general characteristics of the stages will be to make as complete a catalogue as possible of the particular features of each of them and especially of the present stage, so that each may present the features of a complete environment. Progress will then appear provisionally as passage from environment to environment. The method will probably assume that successive environments are more advanced and consist in higher (though potential) realities. The mind will conceive of the higher environments as though they already existed and it were only necessary to open a door, as it were, in order to enter them. It will, of course, soon be perceived that there is no such regular succession of distinct environments that can be contrasted with each other. Some phenomena will continue very much the same, while others are often changed or replaced. When change is once recognized as taking place, it will soon be found that there is really no instant when some change is not taking place. Every moment is characterized anew. Thus the environments will gradually be reduced to infinitesimal lengths of time and the conception will arise of a

[1]Such appears to be the method employed by Professor Patten in his *Theory of Social Forces*. The writer does not wish Professor Patten to be held responsible for all of the suggestions made in the text in this connection. There is danger of misconstruing a novel method.

kinetic rate of progress. The theory of progress will then have reached the full kinetic stage.

While in the static stage of contrasts, however, the theory of progress will already contain kinetic elements. Instead of taking various social elements and building up social conclusions out of them and thus bringing them often into strange relations, it will assume the condition and action of society as a whole to be the simple unanalyzed fact. It will therefore start in accord with common experience and bear a kinetic stamp from the first. The business man and the statesman always deal with the matters in which they are interested as wholes. Their materials have a way of acting with which they are become familiar and with reference to which they instinctively take active measures. The business man does not stop to think whether prices are due to the production of gold, to the state of credit, or to the production of commodities. The statesman does not stop to think whether attacks on the banks are due to the materialism of the public, or to the survival of the lower elements in the development of civilization. To the statesman public opinion is public opinion.

Perhaps the most useful phase of the method of treatment here outlined is in the fact that the recognition of assumed sudden changes in environment is actually quite warranted. It is far from true that nature does not at least appear to act in a revolutionary manner. The gradual change of the seasons is marked by storms. The gradual movements of the earth's crust are marked by earthquakes and volcanoes, by "flaws" and "dikes." Political history is marked by revolutions, and economic history by crises. It is possible that these phenomena are superficial and that laws may be formulated that continue their uninterrupted work after, as well as before them. Nevertheless, it is true that the face of society, like the face of nature, presents a very different aspect after one of these interruptions. It may be true that *natura saltum non facit*, but it is also true that "it is the unexpected that always happens." The striking phenomena must not be omitted simply because they are superficial. Our theory must find a place for them.

It is possible that this method will enable the Economic Crisis to be studied with better success than heretofore. Crises have

been described as "growing pains." Industry is not the same after them as before them. New organizations are attempted, new inventions are made and utilized; business men adopt new opinions, governments modify their economic policies. Nevertheless, the fundamental laws of production and distribution probably hold true the same afterwards as before, only they are understood in a still more fundamental sense. Competition is no longer understood as the rivalry of small business concerns. Stimulus is given for new inspection of every relation of life and for a corresponding rearrangement of views. It really does seem as though the human mind was realizing an environment that had already existed potentially, as though it had entered a house that had always stood ready-furnished to receive it. A further and more kinetic step in theory will be to determine how far the mind adapts itself to a house already existing and how far it creates the house.

Crises are those economic phenomena most in need of the light of kinetic logic. In order that we may understand them it is necessary that we construct, provisionally, at least, a theory of progress, since a crisis is essentially an episode of progress. In accordance with the preceding theory of logic, some environments are low, others are high; some are primitive, others are advanced; some are materialistic, others are psychic. The theory of the crisis proper will therefore necessarily be preceded by theories of the materialistic conjuncture, of the psychic conjuncture, and of the process of progress. Into this more kinetic framework the theory of the crisis proper will then be easily fitted.

## II

### THEORY OF THE MATERIALISTIC CONJUNCTURE

A catalogue of the materialistic conjuncture[1] includes all tangible useful articles, whether they correspond to institutions (which are psychic phenomena) or not. We may roughly class the forms of the materialistic conjuncture into (a, environment proper) the crust of the earth (Patten) and (b, conjuncture) mechanical inventions and other more or less artificial modifications of matter, which might be regarded by themselves as constituting a conjuncture or quasi-materialistic environment.

Thus we find a continuous series of conditions that must be grouped together in order to afford a static contrast with the psychic groups: (a) The crust of the earth, including improvements made by man; drainage (Holland), artificial islands, clearings of timber or stone, holes made for mines, exhaustion of atmosphere by combustion and breathing, dams, levelings, bridges, roads, walls, buildings; (b) heavy machinery like docks and locks, cranes, Bessemer retorts; light machinery such as looms; movable machinery like wagons, cars, ships, locomotives; and apparatus for comfort or convenience, cloths, hand-tools, watches.

In general, as the material modifications become more portable they correspond more to active mental states. Men think of them more often. They need more frequent replacement. Hence the material and psychic conjunctures tend to overlap at this end

[1]The writer has employed the terms "conjuncture" and "environment" as synonyms, roughly speaking. The former term, however, seems to him to connote a shorter-time point of view than the latter, and hence less of fixity and unmodifiableness Therefore, he has allowed himself to use the two words generally in a similar sense, but taking care, in his selection for any particular content, to note whether it calls for a little more or less of the idea of durability. The reader will notice that the terms "environment," "conjuncture," and "process" are employed to designate continuous points of view, beginning with the most materialistic and permanent, and passing over into the most psychic and temporary. No separate treatment, however, has been given to the "conjuncture" apart from the "environment." It has been preferred to set them both over against the "process"; indeed it is difficult often to draw a line between the more and the less in the matter of environment; but, since the less cosmic point of view is the one that touches us most, it has been preferred to use the term "conjuncture" unless it is quite plain that very durable conditions are under consideration.

of the series. The materialistic conjuncture forms at any given moment an harmonious whole. It is composed of objective utilities, i. e., of items that are useful to each other: each complements the whole, which would, in its absence, be defective. This is the kinetic interpretation of an economic utility. Thus in 1825 the scythe, the forge, the anvil, and the bellows, primitive looms and cards, and spinning machinery driven by water or by weak, high pressure steam-engines, domestic manufacture of shoes, clothing, etc., domestic slaughtering, transportation with oxen, bad roads, sailing ships—all formed parts of one objective, material whole. A modern mill could not then have gotten supplies nor have sold its output. A modern railroad could not have made its expenses. To-day or even by 1875, none of those old methods could have competed. The very goods produced change. A machine-made shoe is not a hand-made shoe. Again, from 1880 to 1900 another complete revolution has taken place. The market has again doubled, the complexity of machinery, its delicacy, its differentiation been revolutionized. Iron has doubled in output, steel has been substituted for iron in the fine products, coal output has doubled, ships and locomotives have been recreated. Every manufacture has equally improved: silk, boots and shoes, house and factory construction, electrical power, renewed use of wind and water power, extension of system of grading products, airbrakes and automatic couplers on freight trains, inconceivable economies in iron manufacture,[1] new prepared foods, improved electrically-driven printing presses, agricultural machinery (blower threshers, disk harrows), phosphate fertilizers, typewriting, telephone. Such improvements immensely further the ability of the organizer, spread out the differences between the able man and the next most able. Big production and big organization are favored.

Very few of these elements of the tenth decade could have existed even technically in the ninth; *none* could have existed economically. The steamer Great Eastern is an example in point. Launched in 1858, she was an economic failure from the start, on account, apparently, of her unprecedented carrying capacity.

[1]See report of visiting British iron masters, daily press for September 27, 1902.

Much of the materialistic conjuncture has been worked out in men's minds. After being worked out in their minds, they have ceased thinking about it; it acts on mere suggestion, as it were—mere impulse of coal, water power; mere replenishment and upkeep. Improvements have purely objective, present economic efficiency, the same as fields and rivers. Hence an improvement once accepted is not a part of the economizing, but only of the economized industry. It produces, but does not economize with respect to present industry. It does not save.

Is this a theory of "materialism"? Does it maintain that human economic destiny is dependent upon and hence formed by matter? Certainly not. Only one side of the case is contained in the conjuncture. Really the assumption of the environment is a necessary stage in the analysis of the relation of mind and matter in progressive production.

All human reasoning is upon a physical, i. e., materialistic basis of analogy—in other words, just as all human economy is built upon a materialistic conjuncture, so is all reasoning about the subjective interests, the thoughts, customs, institutions, and actions of men explained by metaphors drawn from the same materialistic conjuncture. Kinetic reasoning is no exception to this rule. The business man speaks of prosperity in terms of quantity; he must measure it in money, which he handles by physical analogy, e. g., sale of a note. Materialism abounds also in the law, e. g., trover or replevin of a note. So the theories of stimuli, of differentiation, of equilibria are purely physical analogies. They are *the only* means of explaining psychic phenomena. The *use* of physical or environmental language or terms is therefore no test as to whether the subject-matter be materialistic or psychic. But the kind of physical analogy employed will be the test as to whether the thought be kinetic or static. Thus, with dawning consciousness with respect to economics, people speak naïvely of a fortune as a given quantity or mass of matter instead of a collection of interindividual rights, of which fortunes are usually composed. This error is made cumulative by speaking of the fortune of the deceased as so much money—of which an estate is almost never composed. A

person worth so and so much is looked upon as the possessor of something permanent which can not be impaired except by physical destruction. But the kinetic idea looks on a fortune as a flowing fluid like a river, that can not be grasped, and can only be kept in channel with unwearied pains. Evidently the kineto-physical analogy is more psychic than the stato-physical. The latter must be used in those lower forms of reality that are themselves static, while the former indicates a kinetic reality; the kinetic reality is the more psychic (cf. III, infra).

A few illustrations of the materialistic conjuncture and its relation to progress may help to clear up the subject. The year 1875 was a turning-point in English agriculture, due to importation of American and Indian grain. The consequent fall in the value of agricultural land was accompanied by a severe depression, which was relieved 1880–83 by the revival in English shipping due to the importation into Europe of grain largely from the countries mentioned. It was not till the end of 1883 that agricultural depression was united with transportation depression so as to produce nearly a state of general commercial and industrial crisis. The falling off in the demand for rails from the United States due to depression in that country increased the English depression. Was this quasi-crisis indicative of a move upward or downward? The only test is the psychic one. Agricultural depression was caused by the opening up of new and distant sources—crop areas. This was made possible by inventions in ship and railroad building. The overcoming economically of obstacles of space and time is the test of a more psychic conjuncture; in other words, the conjuncture is more psychic when man is technically less impeded in space and time, and hence has a wider scope for his economical activities. India was little available economically in earlier periods—for the European market. Argentina had been hitherto unsown. America had but just filled up the central west. Railroad and shipping rates were rapidly falling.

Here was a new environment—because physically wider—partly of virgin soil, but embracing also the oldest country, India. The question of materialistic or psychic conjuncture is

largely the question of the size of the market. Biologically, the market is the test of the conjuncture,—it characterizes or sums up the whole conjuncture. Inventions, speed of communication and production, rapidity of accumulation of wealth,—all indicate greater influence of will, greater proportionate share of mind in whatever affects human life (both individually and socially speaking) in comparison with that of matter. Man has advanced, but by his own efforts. The new local combinations bring together or *economize* the preexisting materialistic but potential environment. What items shall make up the new conjuncture is a matter for experience, that is to say, experiment. India has subsequently not advanced but rather fallen back as a part of the conjuncture or market. Russia has advanced enormously compared with her position in the early eighties. The Argentine Republic has made the greatest advance of all, especially in the nineties. The United States actually fell back in wheat area from 1882 to 1894; however, her yield was so large as to more than compensate for decreased acreage. Her good harvests thus defeated the object of the decrease of acreage, viz., to accommodate herself to the competition of India, Russia, and Argentina. Thus the environment, so far as it is composed of wheat lands, has continually shifted. The potential environments are always there, but what items (in this case geographical) shall constitute them is a matter for experience and for tentative activity.

The availability of a given (e. g., geographical) item for the conjuncture at a given moment is evidently determined by local as well as by foreign conditions. It is the local psychic as well as materialistic conjuncture that is decisive. The caste system of India is unfavorable to industrial enterprise; the tax system is also unfavorable. These conditions inhere in the Indian type of mind. Light yield, small holdings, hand labor, undeveloped transportation—all conspire to make India a high-cost producer. Small holdings are not necessarily so uneconomical; in France small holdings offer some disadvantages, but these are partly made up by rotation of crops, manures, intensive culture, and cooperation for larger work, such as power threshing. Hence

the higher psychic quality of the French mind tends to keep the French soil within the momentary materialistic conjuncture.

The higher, more psychic conjuncture is wider. This means that it gives room for more investment and for more produce. In its crudest form its efficiency consists in literally extending the geographical areas involved—not merely by transporting produce from a more distant place and thus bringing it within the market, but also by adding new areas not previously cultivated. This is the crudest form of widening the environment. It was the sole means in earlier ages. By migrations and colonizations ancient men lengthened their journeys, widened their plans in space and time, broadened their markets; and thus from the material, geographical side literally widened the environment. They first found the environment, then made use of it. Very little scope now remains on the earth for this primitive method. Argentina is the best example of recent times in the wheat part-market; Africa, in the gold part-market. But the real test now of the entrance of geographical items into the conjuncture is whether they offer the proper psychic conditions. Thus both France and Argentina, though so unlike in situation and climate, are more permanently in the market than India. It is true that France exports and imports but little; but this little keeps her in the wheat market.[1] Argentina is a simple case of the successful trial of a new field and the discovery that it belongs to the present and coming environment. England, on the contrary, in order to stay in the agricultural conjuncture at all, has been compelled to change from wheat to beef, and, in the change, to lower greatly the valuation of her agricultural land. Evidently, the less favorable soil and climate of England can not compete in the wider, more psychic market, which is seeking out all the potentialities of wheat culture hitherto neglected in the earth's crust.

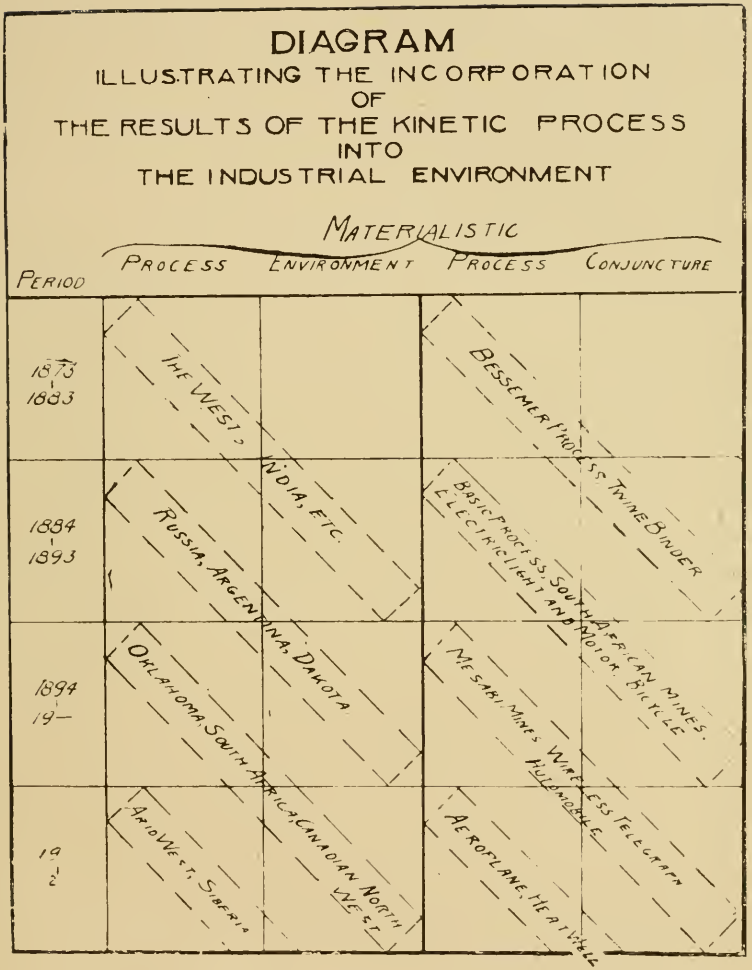
Which, now, is the *cause* of the progress in wheat culture into the larger, more psychic environment,—the crust of the earth or

[1] "Grain prices in France were regulated by the world-market at the period when that country still supplied, on the whole, its own needs and only occasionally made good a slight deficiency from abroad, or exported a light surplus." Prof. I. Conrad, *Die Stellung der Landwirthschaftlichen Zölle*, p. 131, Schr. d. Vereins für Socialpolitie, LXXXX.

the new inventions that "annihilate space and time"? This is a purely casuistic inquiry, but one that the popular attitude demands. The word "cause" is employed in many senses. If we mean those perpetual potentialities without which life and progress could not exist, then the mere existence of Argentina, France, India, Russia, the United States, with their natural climatic, hydrographic, and meteorologic conditions, is the *"cause"* of progress. If by "cause" we mean, not unvarying potentialities, but active measures of intelligence adopted (generally through fear of retrogression, e. g., a strike, or pressure of competition, in the first instance) in order to attain to the wider environment potential upon the earth, then we are taking a very distinct and different point of view. The former sense is natural in treating of the materialistic conjuncture, but only in a qualified sense of the psychic conjuncture. It is the environmental or conjunctural meaning of "cause." The latter is appropriate when we are treating of the laws of progress—the mechanism of advance into the more psychic conjuncture. In each crisis those items are selected for further addition to the materialistic conjuncture which the existing environment finds truly cooperative. In this selection the existing environment plays a wholly passive role: its position is secure; the question alone admissible is whether the new items so conduct themselves as to utilize *all preexisting* elements. It is probable, indeed, that some preexisting elements may diminish in importance, temporarily at least; it is even possible that they may be disused; but observation shows that the economy of nature does not favor waste in the evolution of the industrial organism. Thus, the ancient use of water power to drive machinery was partially abandoned for a long series of years after the adoption of steam power; many mills on (e. g.) the Connecticut and other rivers substituted steam for water power. But now that the progress of electrical science allows of the distant transmission of power, the great cataracts of the world, which never run dry, are furnishing a source of industrial power infinitely greater and of greater constancy than steam. The same technique that belonged to a primitive, narrow environment may reemerge into a higher, broader one. We may

# DIAGRAM

ILLUSTRATING THE INCORPORATION
OF
THE RESULTS OF THE KINETIC PROCESS
INTO
THE INDUSTRIAL ENVIRONMENT



expect that the final environment, at the last, ideal stage of progress, will have economized all possible technical elements, the whole crust of the earth.

With reference again to the superficial, wheat conjuncture, the crisis of 1883–84 began with a widening conjuncture of wheat land to which India and the West were not yet added, but were candidates for incorporation. After the crisis, the West was found to be a permanent addition, while India has remained in a rather tentative position. Subsequently, and up to the crisis of 1890–93, it was Russia and Argentina and Dakota that sought admission, and the test of the crisis decided that they were all to come in. Subsequently, experiments have been made with Oklahoma, the Canadian Northwest, Siberia, and other localities. The exact importance and permanency of these additions to the physical, materialistic environment are not yet settled.

In a less superficial, physical sense, the new environment contains all that congeries of apparatus which industrial experiment has approved and a crisis has not eliminated, e. g., acetylene gas, bicycles, chloroform, dynamite, steam dredges, electrotypes, fire engines, fountain pens, galvanic batteries, harvester-reapers, knitting machines, kinetoscope, liquid air, matches, macadamized roads, wire nails, phonograph, planing machine, pneumatic tires, the propeller, Roentgen rays, sleeping cars, Bessemer steel, steel pens, sewing machines, Suez canal, telephone, telegraph, typewriters, vulcanized rubber.

## III

### THEORY OF THE PSYCHIC CONJUNCTURE

The psychic conjuncture consists primarily of those fixed or rather constant ideas which we take for granted in industry, and which are therefore a part of the conditions under which we act. Those ideas are subjective in the sense that they are psychological and within us as individuals; but they are objective in the sense that they are always the hypotheses and never the conclusions of our thought. Moreover, they are normal and hence social among industrial men. Of course, all human institutions have a more or less direct influence upon industrial thought; but as one of those more specifically economic, I would mention the great institution of credit, with its appropriate paraphernalia of banks, trust companies, clearing houses, bill brokers, exchanges and boards of trade, guaranty funds or "reserves," money markets, discounts, and establishments for savings, insurance, cooperative building and loan, agricultural credit, etc. Evidently this great institution of credit by which we are enabled to adjust the personal obligations arising from our acquisition of distant or future goods by means of near or present payments, thus liquidating and acquitting our personal obligations with further recourse only in cases of accident or fraud—is the most gigantic department in modern industry.

Another example of the nature of the psychic conjuncture is the division of society into industrial classes. This constant idea, this caste idea, gives us an opportunity to test the objectivity of the psychic conjuncture, its non-ego characteristics. According to the socialists, the different industrial classes arose with modern capitalism; they admit that these classes were made possible by capitalism, and they claim that capitalism must be abolished in order to abolish the class distinctions. But they mean to abolish capitalism without abolishing the improvements that were the conditions precedent in its creation. These improvements were the condition of the creation of the classes, but are not the condition of their perpetuation. This seems improbable.

As we ascend in the psychic scale, the more psychic elements can only be modified as they correspond to the materialistic basis or substructure already provided for them. Thus we have already seen that there can be a geographical expansion of the market only as new countries are opened up, or as new inventions disclose wider possibilities in old countries, either by redeeming waste places, by more intensive cultivation, or by stimulating new desires and exchanges. Statically considered, all the elements of a complete conjuncture are to be taken as reciprocally harmonious. While it is true that machines—a quasi-materialistic part-conjuncture—can not be employed, however adapted to the soil, climate, etc., unless a sufficient market—a psychic conception—is at hand, or capable of being worked up within a reasonably short time, it is also true that some of the elements are to be taken as prior in the field, as it were,—as more ancient and permanent, and as exacting conformity from the others. This hierarchy of elements exists in a continuous row or series, beginning with the most materialistic and passing over into the more psychic. Thus not one of the improvements that form a part of the materialistic or quasi-materialistic conjuncture but was in the beginning vigorously conditioned by the crust of the earth. In fact, large classes of improvements are denominated by that philosophy of language which is the best proof of the predominance of the social mind over the individual consciousness—"discoveries." Chemical discoveries are manifestly but the isolation of chemical properties of the crust of the earth for man's behoof. In principle, mechanical inventions are in no respect different. Once "discovered" or "invented," improvements blend into the crust of the earth, become to man a part of it,—become in fact first conjuncture and then environment.

Next in the hierarchy we have to note the institutions themselves. They are in turn conditioned upon the more materialistic elements—the crust of the earth and the properties of it that have been isolated for man's advantage. Thus we are brought back to the question of the unavoidableness of the industrial classes, that is to say, of the classification of persons engaged in industry. This follows as surely from the use of machinery as

does the machinery itself from the untouched crust of the earth. Given a certain complex of machines, they must be served by a certain complex of workers, some tending the more materialistic processes, the raw materials, the cranes, and the like, others finishing the more delicate product, and others, still higher, keeping the whole process in mind, foreseeing what provision must be made in order that continuous work may not be interrupted, assigning the several lower workers to the machines to which they are best adapted, and studying the irregularities, the failings, the shortcomings of the subordinates, in order by hook or by crook, by reward, by cajolery, by threat of lowering of the distributive share of the product, to keep them continuously at their tasks, and to keep understudies ready to step in if a worker default. These higher workers, then, must be students of the psychology of the lower workers, must possess a firm will, a strong personality, a high intelligence, and in every way lead a more psychic life. These are conditions set by the materialistic conjuncture. Given such a conjuncture, the grades of workers must be such as they are. We may imagine government supervision, control, or ownership; if the new method of choosing the classes of workers be not efficient, industry will suffer, will not continue to inhabit its present dwelling, but will relapse to a lower environment.

For example, what do we find to be the result of insufficient moral qualifications in captains of industry? Take the trust as an instance. The only condition under which trusts can prosper permanently is that they be not organized for the purpose of wrecking them or sucking them dry, but that they be managed as going concerns intending to offer their products to the public at current rates of profit so long as said products are in demand and hence harmonize with the conjuncture. If the captains prefer to put up prices, and to take every means to get a "rake-off" from a temporary corner, their organization is sure to suffer; latent competition will become active and aggressive, the work begun by competitors will be finished by hard times and by the courts of bankruptcy or insolvency, and a whole branch of industry will be relegated back to smaller industry, to more primitive

methods, in fine to an earlier, more materialistic environment. This part movement may become a general movement of retrogression, if the general run of trust magnates prove deficient in moral quality. On the lower plane there is less division of labor, less specialization, less scope for talents of the highest order, less guaranty that employment be found for all.

Again, the obstinacy of employers' syndicates, such as the anthracite railroads on the one hand, and of laborers who demand an influence in corporate management not warranted by their psychic level on the other, may result in such inconvenience to the general public, in such a congestion and lack of circulation and supply in the general voluntary industrial organization, that the latter may seek, through the intervention of government, to make common cause and thus consciously and by compulsion to accomplish what was previously attained unconsciously, freely, and organically. If such intervention last a long time, it must surely result in a less skill, a less energy, a mechanical routine of red tape, which will arrest the development of the industry, will cause it to cease to impart stimuli to other industries or to receive stimuli from them, and thus to prevent accommodation to a wider market, if not actually narrow the existing one. If the intervention last but a short time, it may be the best available way for society to defend itself from the immorality, the unsociability, and the shortsightedness of certain classes and industries. Probably such intervention is typical of the most useful function of government. This illustration is in accord with that theory which predicts the gradual shriveling of governmental powers, or, in other words, that the higher conjunctures will make less and less permanent place for them.

Thus we perceive that the successive conjunctures condition the functions that are active in them. The conjuncture or environment is, in fact, the structure within which the functions act. If it is sought to exercise a given function, or business, it must seek out the proper conjuncture, or else fail of its peculiar sanction. In this quest, it may carry the whole industrial movement along with it, either in advance or regress. That in the long run the movement is psychic and hence an advance is the assumption

of this study. If the movement is not propagated all along the line, then the particular industry must fall out of the great world market, and be an example of reversion to a primitive or to a premature enterprise, as the case may be.

The régime of protective tariffs affords one of the best examples of the psychic conjuncture, because it is one of the most psychic institutions and most difficult to trace in its dependence upon the materialistic conjuncture and in its industrial effects. In the frequent tinkerings of the tariff we are to see chiefly the actions and reactions to be considered under the industrial process. In the difference in tariff policy between different countries, we see reflected the differences in the other elements of their respective conjunctures, and most obviously in their materialistic conjunctures. Thus, it is generally recognized that the dominance of free trade convictions in England is assignable to its geographical position at the center of the commercial world, to the decay of its agriculture, which has rendered it still more a commercial country, and finally to foreign competition with its manufactures, which has brought its carrying trade into still greater prominence. A carrying trade abhors tariffs. So well had England succeeded in making herself the "workshop of the world" that all other nations were convinced that the infant industries argument applied to them, and raised high tariffs.

So much as to the respective policies of the different countries; but, in the larger theater in which we are chiefly interested, the elemental economic forces work themselves out less in the light of man's consciousness. No one is concerned to plan the tariff policy of the whole world—its benefits to mankind. Free traders dwell on this subject, perhaps, academically, but on the hustings we hear no note but national self-interest. How is it, then, that without conscious plan the concert of nations vibrates from modified free trade to high protection, and back again?[1] A suggestive solution of this enigma was that of Mr. David A. Wells, who remarked that the protectionism of the eighties was a reaction from the fever heat of production and exchange which had been

[1] The facts of the world-fluctuations of tariff and free trade are stated in the writer's article, *Protection, Expansion, and International Competition*, Annals of the Am. Acad. of Pol. and Soc. Science, Jan., 1904.

stimulated by the free trade of the sixties and seventies. Competition had exhausted the whole field of investment, with the result of low prices and low profits; credit became cautious and restricted, producers still more cautious in asking for credit; economy was pushed to the last point, while the inventions that could be looked upon as safe and "environmental" had reached a limit. Material wealth was, indeed, rapidly increasing, but not at an increasing rate. The psychic condition became intolerable, aggravated as it was by a relative overproduction here and there. The whole organism became supersensitive. The case is analogous on the psychological side to traveling companions who have been too long thrown together in each other's society; they have heard all of each other's stories, they know each other's points of view; they become tired, then petulent, captious, fault-finding, and finally a nervous breakdown occurs, followed by a disagreeable separation, permitting new associations and fresh stimulation.

Professor Patten also has put forth the doctrine of the necessity of industrial and social isolation for sake of the development of the several communities. It is indeed interesting that eminent authorities representing such different points of view should come so near agreement. There is probably here a principle of social psychology in need of further investigation and better recognition. It would appear that industrial stimulation may advance division of labor too rapidly; for division of labor involves fixed individual relations between producers, who have some right to be heard upon any proposition to break up those relations, which in old countries are quite institutional and hence environmental.

## IV

### THEORY OF THE PROCESS OF PROGRESSIVE DIFFERENTIATION: THE WAY IN WHICH INDUSTRIES ARE MUTUALLY ADJUSTED IN THE PROCESS OF PROGRESS

### *A. Analogy of Equilibrium*

The proper logical distinction between this topic and the two that have preceded,—between differentiation and the environments, or conjunctures,—is the distinction between short- and long-time causes. It is confusion of these fundamentally variant views that is the cause of bad logic in most cases, and it is only common sense or good judgment that supplies the needed corrective where sound conclusions are actually drawn. Good judgment has already been explained to be the capacity or ability, innocently of self-consciousness, to combine a number of static positions in such a way as to produce a kinetic conclusion, one that is real to life as practically apprehended. Writers and readers instinctively shift the scene of the drama from the practical to the ideal, without the help of explanatory clauses. Let them fail in this, let them carelessly state or connote ideal premises in connection with practical conclusions, or the reverse, and they are confronted with a *non sequitur* which the untrained mind does not readily notice. Only too often a similarity of phraseology applicable in the two environments, the actual, practical, or present, and the abstract, theoretical, or future, helps to mislead the unwary. The error consists in the failure to note that one part of the reasoning has reference to a shorter period of time than another part, for the terms used are, in general, equally applicable to long and to short periods. For example, by the clever distinction between labor that is merely productive and labor that produces solely for the consumption of productive laborers, Mill is able to distinguish between labor that is devoted to production for immediate consumption, and labor the product of which is destined for ultimate consumption only in the indefinite future, i. e., capital; for productive labor is defined as labor which results in any material product, having value, even though it be a

luxury, while labor for productive consumption could produce only laborers' necessaries. If only the latter labor were employed, all surplus would necessarily, other things being equal, be saved for multiplied further production,—and so on, *ad infinitum*. By devising this logical contrast he succeeded in drawing the great moral lesson that only by saving does wealth increase.

The moral lesson, however, was partly at the expense of experience, and hence was not likely to sink deeply into minds not of a doctrinaire or puritanic type. Wealth created by new inventions is only remotely or secondarily, at most, due to the intention of saving; it may be so recent that there has not been time to consume it or otherwise to determine its destination. The ideal premises of Mill, relating to ultimate social effects, are given a practical application not warranted by experience: the conclusion is reached that now, to-day, we should not indulge in any luxury. Only minds addicted to the practice of abstractions can easily reach and hold Mill's conclusions and at the same time make the allowances due to the momentary conjuncture. Such minds doubtless feel from the beginning the wholly idealistic environment. Again, when Mill's argument passes over to consideration of the effects of circulating and fixed capital respectively, one feels that the point of view is not quite so long-time. The "capital" here spoken of is not that ideal capital that was to be heaped up indefinitely, but is that which either does or does not, may or may not, within a reasonable time and with little delay, support laborers. The two discussions,—on luxury and on circulating capital,—are contiguous in the arrangement of the book, and yet the transition from long- to short-time point of view is not expressed.

Again, in his chapters on credit, Mill speaks of "capital" in the financial sense of the promises of men as to their mutual dealings in abstract value. But he elsewhere defines capital as food, shelter, tools, and clothing of laborers. Here again the experienced student at once reads the future (or promise-) environment into the text, but the inexperienced is hopelessly left in the rear. The fallacies of the popular conception of the quantity theory of money are clearly due to an ignorance of the fact that

moneyed capital consists not of consumable goods, nor of material money, nor even of government notes, but of promises, founded upon or rather recording business contracts (whence the principle that "business makes money"). The double change into a psychic and a future environment is not noticed. It is not intended from these criticisms to develop a theory of distribution; the above instances are adduced in order to show what difficulties arise in the absence of the theory of environments or conjunctures, which allows us so easily to discriminate between long- and short-time causes. The use of this test allows us to bring into self-consciousness many of the elements of common sense judgment that heretofore have not produced their conclusions by virtue of self-consciousness but because of a practical sub-consciousness.

The questions of orthodox political economy are of course not precisely the same as those raised here. They relate to production and distribution in any environment which admits of competition, and to the economic weal of classes or of typical individuals. The separate environments there supposable are not, therefore, precisely the same as those visualized in the theory of progress, for the individual may be assumed to pass from one part of the general environment to another, whether the latter progress or not. And yet they are not so unidentical as one might suppose: the larger movements of industry are taking place *pari-passu* with the rise and fall of individual fortunes, and in fact, are composed of them. Even supposing no progressive change in the general industrial environment of the individual, his fortunes pass, as just remarked, from one (more materialistic, technical, or quasi-technical) part of the given environment to another (more psychic, involving "credit" operations). Who has not read of the brakeman that rose to be president of the railroad? These part-environments are therefore arranged locally or contemporaneously, at least, in a hierarchy corresponding to the successive environments conceived of as constituting the progress of the whole. Since the topic here treated is that of progress, the part-environments enter but little into the argument, and do not need farther notice. They are mentioned

here in order to show that the clear conception of environments would have been helpful to orthodox economies by keeping always in view the distinction between ultimate tendencies and the immediate effects of a given course of economic action, whether in the case of society or in that of the individual.

The present discussion has to do essentially with short-time causes, with forces, with motion. These causes act, not by preventing motion, nor by confining motion within given channels as do the environments, or conjunctures, but they rather embody the motion itself. The more psychic elements are ever in motion, and are ever put to the test of valid normality by the more materialistic. Those that fail in the test are rejected; or, to resume the physical analogy, those that do not conform to the crust of the earth lose their energy in its mass. Taking the example of a machine, its relatively environmental part consists of the frame-work, its causal part consists of the moving pieces (not to speak of the steam or electricity, usually quite invisible or intangible). Now, we do not look upon the tanks, pipes, and retorts, nor upon the frame-work, as constituting a process; we look upon them rather as the necessary conditions of the process: they are the structure, not the function. The chemical reactions and molecular space-transformations are the process. The "causes" of the product, in this sense of the word, are the forces at work in the transformation from moment to moment without regard to the permanent conditions, the frame-work of the machine.

Clearly it is a casuistic misfortune that the word "cause" has this double meaning. All controversy as to whether the structure or the function is the true cause is waste of time; and yet much casuistry is of this order. It is as if two boys were each named George, and then a dispute should arise as to which was the true "George." Nor is it worth while spending much time on the inquiry whether it is in the environment or in the functional processes that we find the characteristically *economic* causes. All processes are economic if they exist in industry, including all the arrangements and promises for satisfying our material wants; and all conjunctures are economic if they condition economic processes. Probably we shall not be able to get rid of this ambig-

uous word "cause," but we may at least make an effort not to let it hoodwink us.

Since conjunctures exist in a hierarchy, since higher conjunctures are progressively psychic, since what is psychic is characterized by motion, and since motion is a matter of process and function, it follows that the general circumstances that we call a process, having motion and a psychic character, may, in turn, be regarded as belonging to the environment when considered relatively to a still higher process. This is the evolutionary explanation of the analogy of society to a moving equilibrium. Industry as a whole is advancing under the fixed conditions prescribed by past advances, as explained in sec. III (Psychic Conjuncture). The moving part is striving for equilibrium within itself and with the static conditions already created; and again, within the general motion are found particular motions of industries and individual workers, which are conditioned by the general motion.

The environment and the process, then, are distinguished, not by the mistaken idea that the one is more "cause" than the other, but by the fact that the process is more recent and more psychic than the environment. The process consists essentially of short-time causes, while the environment consists of long-time causes. Among the short-time causes, acting and reacting on each other as they do, some are relatively more psychic and some more materialistic, as will be hereafter described; but all short-time causes tend to become psychic, or rather the psychic tends to preponderate with progress. The process consists in the action and reaction of relatively short-time causes. It contains the life and movement so far as that is not already become relatively static and environmental.

Consider the supposition of a stationary state, made by Mill, and the similar supposition of a normal equilibrium, made by Marshall, in which "the aggregate expenses of production might be found either by multiplying the marginal expenses by the number of units of the commodity; or by adding together all the actual expenses of production of its several parts, and adding in all the rents earned by differential advantages of production. . . .

The average expenses could be deduced by dividing by the amount of the commodity."[1] . . . This concept excludes that of progress and hence that of a kinetic process. This is a process, but a static process, one that is not becoming old relatively to a newer one, nor new relatively to an older one; in other words, a process that does not blend into environment, but goes on monotonously making the same motions within the same containing walls—the same old grooves and channels, the same conjuncture.

In the kinetic economy, however, which is not an abstraction, but is reality, the conjuncture continually takes on a more psychic character, and the process always keeps ahead, weaving a permanent web, recombining old elements, making new and more complicated combinations out of previous combinations, and putting all its products to the test of acceptability to the environment—the permanent results of past marginal effort.

Primitive, physical, short-time causes will always produce effects on man's welfare. For example, it is possible to trace the effects of the vicissitudes of the weather upon the markets from one year's end to the other.[2] It has been shown that modern industrial crises have quite uniformly followed a period of deficient rainfall.[3] On the other hand, it is a commonplace of economic doctrine that man's welfare is rendered by progress less and less dependent upon his physical surroundings. The better the drainage, the regulation of streams; the greater the prevalence of afforestation, of irrigation, of protection for live stock, of veterinary surgery; the better agricultural and mining machinery and transportation methods,—so much the more secure is the population in its supplies for material wants; so much the more is it emancipated from dependence on short-time physical fluctuations. The short-time physical influences are then becoming relatively less important than the psychic. If the community is deprived of coal and hence of a most materialistic supply, due

[1] *Principles of Economics*, 4th ed., vol. 1, p. 520.

[2] Professor R. de C. Ward, *A Year of Weather and Trade in the United States*, Popular Science Monthly, September, 1902.

[3] H. Helm Clayton, *The Influence of Rainfall on Commerce and Politics*, Popular Science Monthly, December, 1901.

to a coal strike, the dominating cause or motion is evidently psychic. The doctrine (in philosophy) of energism, if it claims that a materialistic cause is essentially psychic in that a common energy pervades all creation, proves too much for the purposes of economic theory. Identity of the materialistic with the psychic can not be economically postulated. They are different phenomena. Doubtless they may be modalities of a higher, common element, from a transcendental point of view. But this can not be the economic point of view, for economics necessarily analyzes phenomena composed of two contrasted orders—the materialistic and the psychic. The moment this contrast is lost sight of, or the study no longer dwells on the continuity between these extremes, from that moment we are no longer within the economic field.

The economic process is evolutionary, and is explained through the analogies of equilibrium and stimulation. By "evolutionary" is meant that we are interested in a large number of phenomena which act and react upon each other with the apparent result of producing progress in the whole. Perhaps it is more exact to say that the progress of the whole is signalized by a complex of changes in the different particulars (wages, profits, capitalism, poverty, inventions, food-supply, organization, prices, monopoly, etc.), and that these changes are so interrelated that a change occurring in one category is always accompanied by changes in all the others. On account of the law of simultaneity, it follows that there must be a fairly parallel development all along the line, and that, if we wish to observe a separate, solitary change we must choose a very short period of time. In such a period one category may have experienced a change before others have been affected. Indeed, we may assume that this is always the case, and that the order and operation of these little successive changes in the particular categories of phenomena (accompanied by a general progress) constitute the process.

The growth of a biological organism is by precisely the same process. Its life-forces assume various classes of forms which are embodied, in each class, in the individuals of that class. These corpuscles, cells, membranes, processes, etc., have individuality,

act with apparent independence, compete for nutrition, in taking they give in exchange, they respond to a series of stimuli, disturbance of their equilibrium is passed on through all other parts, creating corresponding and proportional disturbance in the latter. In so living they progress, and with their progress the whole animal or plant progresses also.

In all cases, whether social or biological, the process is essentially one of a succession of stimuli and of a succession of disturbed equilibria. The physical explanation of equilibrium has its classic origin in the field of international trade. That was the field that first attracted man's attention. In rising international commerce men saw marked, decisive movements that could be distinctly contrasted and measured. It was practicable for large dealers to keep pretty close watch of the quantities of merchandise, precious metals, and commercial paper that moved in and out of a country. The conception of a normal equilibrium thus emerged from salient conditions at the dawn, as it were, of the complex organization of industry. To extend this conception to the vastly larger field of domestic industry is the task of the systematic bringing together of theory and experience. In the category of credit this task has been partially accomplished; in the categories of production, consumption, and distribution it has barely begun.

Consulting statistics of trade balance[1] we note that, conformably with the general movement for paying off our foreign war debt, which began in 1875, simultaneously with or just before the deficiency in English and Continental harvests that lasted roughly from 1875 till 1881, the years 1880 and 1881 mark a rather large surplus of exports. There was heavy railroad building at home, 1879–81. The equilibrium of production at home was thus disturbed in the direction of a heavier demand for rails; abroad, the equilibrium of agricultural demand and supply was disturbed by deficient supply due temporarily to poor crops, but in the long run due to a comparatively high cost of agricultural production. The poor crops were a short-time cause, an

[1] Cf. *Monthly Summary of Commerce and Finance*, June, 1900, p. 3424, Imports and Exports of Merchandise and Excess of Exports over Imports.

occasion, which started the disturbance in the agricultural market. The comparative cost of production was the long-time cause, soon blending into the permanent materialistic environment, which prevented the return of agricultural production to its pristine fields. It will usually be noted that those changes that are to become permanent environmental conditions do not operate except some adventitious or sportive element throw the burden upon them. They do not come forward of their own accord and directly change the current of affairs; they exercise their controlling power only upon occasion; but the occasion usually arises, provided there be in the industrial economy a sufficient content of energy, action, motion, enterprise.

It is not surprising that the demands of England for grain were more permanent than those of the United States for iron and steel, since the agriculture of England was decadent, whereas the domestic American steel industry was nascent and vigorous. The close of the Civil war, the liquidation of post-bellum speculation fostered by paper-money financiering, the return to specie payments, the oblivion of the losses of 1873, had furnished the psychic, social conditions for a return of industrial enthusiasm. This attitude of the industrial public was more than an occasion for a positive movement:—so long as it lasted it formed a subjective condition of the continuance of the movement. The fact that England now greatly increased her unfavorable balance of trade, however, acted as a temporary stimulus, in turn, to English industry. The volume of trade was large and consisted of raw material, such as grain brought from India, America, or Russia, or of bulky articles, of no high or remote degree of manufacture, such as rails. In marine transportation comparative cost lay in favor of England. It was twenty years since the equilibrium of transportation cost had been permanently adjusted in her favor.

The business of shipping, therefore, took a great boom in England 1880–82, and this specialized prosperity obscured the great calamity to agriculture. The domestic liquidation due to that calamity was put off. The earnings of transportation were diffused through the credit system of England and lightened the

downfall of agriculture. Better crops fed the mouths even if the prices were not such as to enable the agricultural interests to maintain their old footing. But by 1883 there was a temporary slackening of demand for transportation from the wheat interests. The iron interests also needed less transportation. Railroad building fell off in a marked degree in the United States in the years 1883–85. The American home demand could consequently be supplied from the growing domestic steel and iron industries. There was a consequent slackening of demand on both sides; but as the English demand for wheat had formerly exceeded the American demand for iron, now a let-up in those reciprocal demands caused a reversal of the disturbed merchandise equilibrium; the scale was tipped the other way until, indeed, in the fiscal years 1888–89 there was actually a slight balance against the United States. The causes, however, had by that time somewhat changed.

Whether the stimulus for this reversal of the merchandise equilibrium came from the United States or from England, as between the two, is a different question. The physical analogy is satisfied by an examination of the reversal and of the changed quantities which go to make up the new equilibrium. These we have noted to be the decrease in demand for iron from the United States and the decrease in the demand for wheat from Europe. The total commerce decreases and the balance of merchandise turns gradually and irregularly against the United States. These are familiar facts, and can best be described without departing much from the language of government experts and trade statisticians. To attain to a high self-consciousness with respect to them is, however, quite another matter. So far, they appeal to us solely through the physical analogy of disturbance of equilibrium. An equilibrium is balanced, or even, scales. If one scale is weighed down, the balance is restored by a weight in the other. Gold and credit are the means of keeping the total balance even, when the merchandise balance is disturbed. But the analogy of the scales is more significant if we suppose industry to consist of a series of scales, and that the disturbance of one disturbs all the rest. Thus a change in the international

balance of merchandise is accompanied by a change in the wheat and iron equilibrium in the American and English markets severally, wheat going up relatively to iron in the United States and down in England. Of course, the delayed liquidation of English agriculture must now take place, and, in America, the delayed explosion of railroad schemes. The violent liquidation of the crisis we leave to the next section, except the observation that for it the analogy of equilibrium also holds.

The disturbance of equilibrium, however, that explains the ordinary cause of industrial progress, is of infinite complexity. The field of international trade is chosen because it is the simplest and most patent. As noted above, a disturbance of international equilibrium of trade is always accompanied by a disturbance of domestic markets, and a disturbance in any one of these is always accompanied by a disturbance in all the others, according to the law of marginal efficiency or substitution. There is, however, no theoretical need that we begin our investigation of equilibrium with international trade. For large countries it is in volume small compared with the domestic. The chief difficulty is that within a country it is not so easy to correlate market disturbances with transportation statistics. We know more accurately how much wheat is sent to England from the United States than how much is sent to New England from the Dakotas. Our treasury bureaux are endeavoring to remedy this deficiency; but they will not make much progress until the railroads are compelled to furnish detailed transportation statistics. It is true that we export two-thirds of our cotton crop, but we do not export a quarter of our wheat crop nor a tenth of our corn crop. In 1900 the export of iron and steel of all kinds was $121,000,000. Now if we suppose all the unwatered capital really invested in the manufacture of those articles in the United States to be one billion dollars, and suppose that capital to be half of or even equal to the annual product—a most conservative guess—it will be seen that the expanded exports of iron and steel can hardly, in those most exceptional circumstances, have equaled one-tenth of the total product of the country of those articles.

## V

### THEORY OF THE PROCESS OF PROGRESSIVE DIFFERENTIATION (Continued)

### *B. Analogy of Stimuli*

The analogy of equilibrium by itself presents to us only static views at intervals. We study disturbances and compensations. If the international balance of merchandise is disturbed, then a further disturbance of the balance of gold or of credit compensates for the original disturbance. If the compensation is of gold, this disturbs the money market in the countries from and to which it is sent, through the effect on the respective guaranty or reserve funds. These disturbances find their compensation in the encouragement or discouragement of speculation or investment, as the case may be. But we do not, in the theory of equilibria, study the succession *per se* of these phenomena. We consider whether *at a given moment* a surplus of wheat on one side is balanced by a surplus of iron on the other, or whether a difference of these surpluses is balanced by a surplus of gold, or credit, or other merchandise. Thus we obtain a series of pictures of static moments. If these pictures be taken at sufficiently rapid intervals, an undoubtedly kinetic impression is produced. But it falls short of reality because the analogy and hence the point of view are too physical, and also because even in the physical analogy stress is not laid upon the *order of occurrence* of phenomena that roughly appear to be contemporaneous, but which really begin successively.

The environmental part of our study was purely objective. We sought merely to catalogue contemporaneous phenomena. As we shortened the time of our survey, objectivity became more difficult and less important. It was no longer satisfying to know that phenomena belonged together in groups. We were confronted with a mass of phenomena that are always present in greater or less degree. We find them fluctuating in quantity from one category to another; pure objectivity demands that we

keep right on with our method and record the contemporaneousness of the several fluctuations,—whether much of this or little of that is present. A point, however, has been reached where motion is becoming the important element, and where its direction can best be pursued as a separate, and, in fact, the principal theme. We are now prepared to understand the business man's point of view. In the quasi-physical sense, we want to know what invention, what business, what enterprise gave the first impulse to prosperity, what was the next one to receive it, the next, and so on throughout the entire list. The need of cataloguing businesses in the order in which they are affected by expansion of trade and by "crises" is felt by those who are studying crisis phenomena, and the present analysis is conducive to the setting of this desideratum in its proper relation to the rest of the complete crisis theory.

The industrial movement of expansion does not, however, act in this quasi-physical manner of causation alone. There is, to be sure, an appearance of stimulus, when one card sets another atumbling and so the whole house of cards falls. A stimulus is that which disturbs an equilibrium; and the more unstable and nicely poised be the equilibrium, so much the less ponderable and hence less physical need be the disturbing force. Consequently, the more the phenomena of industry are those implicating functional motion, and the more nicely poised they are for the play of such motion, so much the more are they obnoxious to industrial influences of a more purely psychic order. In fact, in organisms, the term "stimulus" is chiefly restricted to the nervous impulses. It is supposed that nerve action always regulates the coordination of the brain, the circulation, the digestion; they are not set at work by mere physical impact. Their particles are in such unstable equilibrium that a nerve current suffices to set them in motion. The steam in the boiler may be liberated to do its mighty work by a tiny electric impulse. It is highly significant that nerve action has been discovered by Professor Loeb to be essentially electric.

According to some popular theorists,[1] there is something of magic in money. The possession of money has seemed to be the

[1] F. Tugan-Baronowsky, Handelskrisen in England, p. 7, sqq.

open-sesame to riches. It is the Aladdin's lamp which needs but a gentle rub in order to realize all imaginable material wealth. What is psychic is indeed mysterious, for it is new to science; and it is precisely because it has not admitted of tangible explanation that the vogue has felt it to be mysterious. The theory alluded to gives some explanation, but not enough to remove the mystery. The explanation runs as follows: In a state of barter every seller is also a purchaser; there is, in fact, no distinction; but in the money economy all is changed; all producers are sellers, and are engaged in warlike competition in order to market their wares. General overproduction becomes possible relatively to money, and even a partial overproduction causes a general fall in prices, since it is well known that something like Gregory King's law is of common occurrence—an increase of amount sold is accompanied by a more than proportional fall in the price of the given article. This is tantamount to a slackening of demand for all articles exchanged for it, and hence to a general fall of prices,—only the given article falls more than the rest. This conclusion may be made to accord perhaps with strict quantity theory of money; a slackened mutual demand means a less rapidity of circulation of goods, a rise of prices, a fall in the value of money, followed ultimately, of course, by a diminution of the amount of money in circulation.

The producers are represented by these theorists as weighed down with the burden of marketing their goods. Those who control the money are the masters; they are exempt from this competition for a market; they have only to wish, and immediately their wants are gratified. The money economy therefore introduces a new and strange force, and the state must intervene to protect producers from its vagaries and malign influences.

In answer, it is to be said in the first place that it is better to look on the change from barter to money-use as a continuous development. Thus, it is a commonplace of orthodox economics that purchase and sale are nothing but a differentiating of barter into two acts that really complete the former simple act, but allow goods to be exchanged in more convenient quantities, money being used to preserve or store the value during the time neces-

sarily occupied. That the credit or set-off system, which is the further development of the money system, allows of exchanges quicker, if possible, than the barter economy itself does not matter to the present discussion.

In the second place, the use of money permits a much more distinct stimulus to be imparted from one business or industry to another. This agrees with the circumstance just mentioned that money allows of the sale of undivided lots, and thus guarantees the success of manufacture on a large scale. Values being generalized[1] and stored up by money are passed on to the benefit of other industries, either through the well-known method of purchase of supplies, raw materials, and labor, or through the generally distinguished method of investment or capitalization, which is really and essentially the purchasing, not of materials for industry A, in which the money itself was earned, but of other raw materials, supplies, and labor, suitable for industry B, in which the money was not earned. The stimulus to general business is equal in both cases. They are distinguishable, from the point of view of business A, only by the difference between a purchase of goods of the second degree and that of goods of the third degree, following Herrmann's classification. Both cases are cases of true industrial stimulus.

In the case of the purchase of secondary goods—materials, labor, etc.—the stimulus is apt to be a more or less continuous one, the interruptions are slight, or merely a minute wave, as in a so-called "continuous" electric current. The essentially psycho-electric analogy is significant, since the money-system allows so much freer scope to the schemes, plans, and imagination of man, systematic though they must be if they would succeed. Through and by the money system man's mind essentially thinks and acts in industry. But in tertiary purchase, or capitalization, the stimulus is that of an interrupted current or even the shock of a Leyden jar. The purchases are made *en masse,* and at distinct intervals. The stimulus is pronounced, theatrical. We now see how differently the theory of the kinetic process looks upon pur-

[1]The late Professor Sidney Sherwood's valuable article, *The Nature and Mechanism of Credit*, Quar. Jour. of Economics, January, 1894.

chase and capitalization from the magnified split between them that the static economy of Mill attempted to draw. Here the difference is an incident; there it was essential. The conclusion is that here a wider generalization is permitted. Thus the producers use money to stimulate each other socio-industrially, and it is not true that the community is to be divided solely into money-controllers and workers in industry.

In the third place, there is truth in the division of the industrial world into one class, whose chief occupation is with money, and into another not so occupied. But is the former class an eminently and exclusively purchasing class, or is it rather a class deserving of psychic contrast with the industrial classes, whose activities are more materialistic? We have seen that among themselves the materio-productive classes buy and sell each individual or economic unit alternately, and that consequently none of their members can be stigmatized as exclusively buyers. Now the existence of a moneyed or financial class is most strongly to be insisted upon. So far the popular theory is right. But it is not especially a buying class. That it exerts a dominant influence in industry is also true,—not by virtue of a practice and power of buying the material products of industry, but by virtue of standing at the top of the materio-psychic ladder. Financiers control industry, not because of the mystery of money, but because of the mastery of brains. They certainly buy more luxuries per capita than others, but the item is not very important in the aggregate, and insignificant if put against the aggregate of luxuries consumed by the lowest industrial classes. Their purchases of other material products, except they become directly investors, are small. And yet they are great purchasers—of promises! A parallel mutual relation exists between the members of this class to that between the members of the materio-industrial class. These also buy and sell some promises, but their chief business is production. By selling promises financiers and manufacturers obtain the "money" with which to buy new promises or wares. Thus the great set-off system is effected by which debt and credit become so generalized and homogeneous that within certain kinds of transactions any individual debt will offset any other indi-

vidual debt in the world, although the debtor substituted be personally unknown to either principal.

The operation of the analogy of stimulus in the psycho-set-off or credit system is interesting and instructive. True to the analogy, the psychic system can not originate within itself the stimulus of industry. A system of trolley cars operates by electricity generated by steam power, the latter in turn generated by ordinary combustion; or else the electricity is still more directly and brutally generated by the momentum of naturally falling water, as at Niagara, Sault Ste. Marie, or on the North Yuba river, California. So, in the credit system, all impulse comes originally from mother earth, that is, from the physical workers and those directly connected with them. But it does not always have that appearance.

There is in finance something analogous to an induced current of electricity, which appears to have its origin in some source peculiarly and exclusively electric and imponderable. Financiers invest vast capitals. Their operations are like bolts of lightning in that they seem to come from the impalpable sky and yet can set mighty forests on fire. But the friction of the clouds and the less known means of producing natural aerial electric phenomena are themselves perhaps generated by the revolving of the earth or by equally molar-physical or cosmical causes.

Although the apparently independent process of investment is only the seeming, and far from being the sole part of the electricity of credit, its stimulating operation is manifest. The desire to invest is sometimes local. From one locality it passes to another, sometimes spreading over the whole industrial world, and sometimes dying out in one place when it is kindled afresh in another. The social mind acts by impulse of imitation, by suggestion of example, refreshed after a period of quiescence. The indicia of indebtedness are transmitted by mail, are anticipated by telegraph, and thus the minute psycho-physical stimulus for investment is furnished. Leaders are at hand in every financial market. They perceive the opportunities for new production, for the economizing and revolutionizing of old organizations. Others flock to the leaders. Combinations of general

indicia of indebtedness are made that stimulate, galvanize into full life and action vast productive enterprises. The leaders make great fortunes, as great, perhaps, as those made by the more direct workers, the captains of the industrial, technical processes; and their fortunes seem to the ignorant to be made out of nothing. And so far to us they can only be accounted for as a reward for an original independent stimulus.

But all this financial stimulus known as "investment" is merely a return circuit—or, if you will, a current induced by the primary current from the earth. The lightning which seems to originate in space and which acts with instantaneous, irresistible power, is really a collection of small individual impulses—the long continued action of the wind, the gradual evaporation of water in infinitely small particles, or the transmission through the air of induced or return currents corresponding to primary currents within the mass of the earth.

In industry there is a circuit similar to that in natural electricity. The transformation of finished products into still further production must take place through the intervention of consumption. The only ultimate consumers are individuals. The process of consumption determines the existence of surpluses. It is the natural necessity of individual consumption that guarantees the individual right of determining surpluses. This economic free-will is the peculiar field of the science of jurisprudence and of the practice of law. Surpluses are hence necessarily atomized in a social division of labor. But the atomizing process of consumption is followed in turn by an integrating process of production. The *dialysis* of consumption is succeeded by the synthesis of production. The dissipation of matter that takes place in consumption can not, however, be followed by a reintegration until stimulating forces or moments are ready to disturb their equilibrium and set them in motion toward each other. With perfect mobility the individual surpluses take the initiative. It matters not in what material forms an individual may have had command over finished goods, or what goods he may have produced,—his surplus emerges, by virtue of the generalizing process of credit, as a right, the peer of that of any of his fellows,

in other words, as a juro-economic value; and he is free to determine that value-right toward what fellows he chooses, entirely free from prejudice due to the material form of the antecedent technical process, from which the value-right emerged.

The collection of values in the hands of financial institutions and financiers is evidently a purely psychic operation. It takes place in several degrees just as the specialization of brute matter into goods takes place in several degrees. The existence of financial leaders is an instance of the leadership that must take place in every category of social life. The direction of the generalized and accumulated rights to a special, perhaps altogether newly introduced, or newly discovered industry is the arch-impetus and stimulus of all industrial life. It is that case of "one-sided" purchase the mystery of which so awes and terrifies the popular mind. Really it is but a return-current of stimulus, passing back from the psycho-industrial groups to the materio-industrial groups. The stimulus of industry may thus be classified into (a) the reactions between the members of the materialistic group, (b) those between the members of the psychic group, and (c) those between the two groups.

It is unquestionable that the element of stimulus is a manifestation in the kinetics of industry that imperatively demands explanation. No process can exist without impulse, incentive, suggestion, stimulus. Not only are certain phenomena contemporaneous, on the theory of equilibrium, but they are contemporaneously in motion, on the theory of stimulus. It is like the steam-engine driving the looms of a factory: the forces of the motor and the resistance of the machines and materials are in equilibrium *except* that there is a slight excess of power in the motor, which causes the different apparatus to move in the order prescribed by the conjuncture, the motion being communicated from one machine to another.

A distinction has now to be made which at once obviates a misapprehension and shows the true relation of the process of stimulation to the whole kinetic system. The analogies of electricity and steam represent the stimulus as originally generated in the crust of the earth and as ultimately returning back to the

earth-source and restimulating it by a reflex action. The theory of successive environments or conjunctures, however, represents the crust of the earth and the psychic conjuncture, also, as purely passive, as simply absorbing or eliminating all uneconomic motion. Thus, at first glance, it may look as though the theory of environments excluded motion (except as incident to absorption) from the environment, while the theory of stimuli places the origin of a peculiar kind of motion, that of stimulus, within the environment. The careful reader, however, will have noticed that the process of differential progress includes both materialistic and psychic elements appropriate to motion in the stage of advancement corresponding to the environment in which industry finds itself. While motion is psychic in that it is an attempt to overcome and thus escape the materialistic conditions of time and space, it is impossible except within a relatively material environment. It is natural, therefore, that impulse for industry should originate in the relatively materialistic environment.

It will be urged, however, that progress is due to the endeavor of the individual or of society to pass into a higher environment, and that therefore it is essentially a psychic matter. Consequently the impulse to progress should arise close to or at the margin of the subjective environment or within the purely financial classes. It is they that gather the surpluses, that select the investments, that calculate carefully and with infinite pains the proper direction of industry. In other words, it is they that explore the path of progress, that visualize the new environment, that catch glimpses of the promised land, while the more materialistic workers are pursuing a sodden routine. Is it not among them that all impulse to progress must arise?

In answer it must be admitted and even insisted that the financiers are in the vanguard of progress. But this is inaccurate language, not placing them scientifically in our system. The real classification of the financiers will be understood by observing the psychological distinction between the mind and the brain. The mind is to be thought of as having an existence unreachable by the senses, and is inconceivable as disposing of physical force. The brain, however, is that psycho-physical organism that con-

trols stimuli. Again, even the brain does not originate stimuli, but simply responds to stimuli originating in the inferior nerves, which are closely associated with the environment.

In other words, stimulus is a force, and as such it must originate in connection with brute matter. We must look for the stimulus to progress in close connection with the industrial process. The primary current that disturbs the preexisting equilibria must start in the lower industries; it is then collected and controlled by the financial brain (itself enlightened by the financial mind), and returns to direct the terrestrial forces toward higher planes. So far as the physical analogy goes, it is sufficient to say that social stimulus is analogous to organic stimulus and hence must originate in those social circumstances which are analogous to the physical circumstances that attend the inception of organic stimulus. However, the resemblance in question is closer than mere analogy. Social stimulus acts only by imitation and suggestion from individual to individual; therefore socio-industrial stimulus is but a manifestation of individual nerve and brain action. Now individual action arises from environmental suggestion. Hence it follows that the original suggestion or stimulus to industry can only arise in connection with those essentially economic processes where man is closely associated with physical activities.

The invention of the Bessemer process was the disturbing and original stimulus that upset the whole set of equilibria established by the liquidation following the crisis of 1873, and made possible the competition of wheat lands, the downfall of English agriculture, the advance of the English carrying trade, the opening of the West, the rise of the steel industry in America, the inception of the age of steel, with all the financial readjustments therein involved. This explanation is neither materialistic nor dualistic. It simply describes the mutual relations of mind and matter,—the materialistic conditions under which mind acts and the psychic conditions under which matter acts, in economic progress.

## VI

### THE THEORY OF THE CRISIS

### *A. The Relation to the Conjuncture*

In the preceding sections an attempt has been made to suggest some of the conditions and processes of economic progress, in order that we might inquire in what respect, if any, the crisis presents a variation from the stato-normal. Why have crises received, comparatively speaking, so little attention at the hands of economists? Why has the consideration of their theory been left so largely in the hands of writers beset by prejudices,—men of the ax-to-grind order, men with panaceas? Why have the former feared to tread where the latter have so signally failed? The cavalier treatment of crises by economists indicates preoccupation with other problems. We do not regard as important that which we do not see clearly. But lack of perception is as likely to be due to a lack of appropriate method as to an absence of the external object. In other words, the habit of static logic renders it hard to perceive aught that is kinetic. Those facts and occurrences that are amenable to static thought have received quite thorough analysis at the hands of economists. The suppositions of free competition and that "other things are equal" (i. e., unvaried) lend themselves to the physical conceptions that "the whole is equal to the sum of all its parts," and even in emergency, that a change in one side of an equation *must* be accompanied by a change in the other side. Thus, after making allowance for an elaborate series of premises and contingencies, we may conclude that there are certain relations between wages, profits, interest, and rent. We may even go further and note that an increase in population, capital, and inventions may have various effects on those relations. But we obtain thereby a superficial conception of economic change. Economic progress does not consist, as Mill[1] is forced by his system to suppose, in increase "in production and in population" alone. Industrial

[1] *Principles*, bk. IV, ch. I, sec. 1.

progress can only be tested by its contributions to a higher, more psychic living. This higher standard may at some times call for a greater population or wealth, and sometimes for a smaller. It may sometimes define goods as having a greater and sometimes as having a less material mass or consistency. Economists find matter for controversy on the point whether the strains of a violin are physical and hence items of wealth.

As for changes in the rate of progress, deviations in its path, temporary pauses or retrogressions, changes in its phenomenal constitution,—these were matters entirely beyond economic science or any science of social polity. Unconsciously, perhaps, the crisis was acknowledged to be that very manifestation that embodied all of these intractable phenomena—and therefore it was ignored! Even the unconscious race-philosophy of language employs in this connection a word, "crisis," that indicates a turning point, a parting of the ways calling for decisive action, a culmination of a series of movements of utmost importance to the industrial world (Κρίνω). And yet the static philosophy of industry says little or nothing on the subject which is really the dominating one, but which it chooses to ignore or is unable to see. The result of this attitude is that the crisis is looked upon as something abnormal, as an unaccountable obsession of the industrial world by malign, unexplainable influences which it is hoped will run away and not come back again to bother the weary brains of men who are trying to account for the happening of industrial events.

The criticism to be passed on static economists' theories of crises is therefore that of deficiency rather than that of incorrectness. Mill seized one of the most salient crisis phenomena when he said that crises were caused by an overfilling of the field of investment, whence resulted a fall of profits, causing speculation and an inordinate rise of prices, succeeded by a corresponding depression of the same. While all this is true, little is said as to the socio-industrial utility of the process, except to insist that it tends to raise profits[1] again. There is here a slight hint of a large process of alternately filling and emptying a reservoir of investment.

[1] *Ib.*, bk. V, ch. III, sec. 4.

One theory claims that capital increases much faster than wages advance. Capital is, however, dependent upon wages for a market for products. The lack of wages causes a lack of a market, the failure of the capitalists, and a crisis. The trouble with this theory is, as Professor J. B. Clark has pointed out, that capital is *not* dependent uniformly upon wages for a market.[1] Another theory varies the above somewhat by showing that producers seek to combat falling prices by widening the market, thus exaggerating the original evil. These theories are pessimistic and inorganic. They suppose that the natural tendency of industry is to gravitate into a state of chaos from which it can only be saved by a clever *tour de force,* or by the introduction of a new order of things conceived by the ingenuity of a mere man. In other words, industry proceeds organically on a continuous downward course, but the organism contains no corrective, no balance-wheel, no ability to right itself. The thought is pseudo-organic for a while, but, at a certain point, ceases to be organic at all and passes off into the realm of prepossession and idealism.

Perhaps the best explanation of a crisis flows from the theory of undervaluation of future goods. If present goods are not valued highly enough and future goods too highly, there will be too much absorption of present goods;—this will be followed by a dearth of present goods and a tumble in future values (i. e., promises). This theory of V. Böhm-Bawerk, which he has not specifically applied to crisis phenomena, is thoroughly kinetic and must form a large part of any comprehensive theory of a crisis. By itself, however, it does not explain the larger social and teleological bearings of crisis phenomena, only the mechanism of some important price manifestations. It is essentially kinetic, however, in that it gives due prominence to the element of time. The time point of view is similar to the kinetic; time is a compendious term for all that happens successively or historically; without happenings there can be no time; a time theory is therefore a theory of those general changes that take place in industry viewed abstractly from the position of pure sequence. Hence a time theory must be very closely allied to a theory of progress.

[1]Introduction to Rodbertus' *Theory of Crises.*

The plain fact that a crisis is looked upon as an interruption of progress made it necessary that we should inspect the nature of progress before attempting to understand a crisis. The further fact that experience so far has been that the interruption to progress called a crisis has not been permanent leads us to inquire whether the crisis may not be assigned a place in the general scheme of economic progress. Remedies for the unpleasant incidents of crises will be in order when once we understand their nature. It is safe, however, to predict that the remedies will not consist in a disorganization of business by an attempt to introduce an ideal,—by directly hindering the accumulation of capital by the passing of minimum wage- or price-laws, or by attempting to preserve "competition" by confining business to small industry.

Economic progress has been here treated as a movement of mankind upward through a series of environments which, in the first instance, are to be regarded provisionally as potentially existing in a rising psychic series, but unoccupied beyond the point to which industrial mankind is actually arrived. Man progresses through an impulse to live a more psychic life, to acquire more psychic standards. As he progresses, however, the conception of environment must change. Starting out with the idea, perhaps, that environment is absolutely or unchangeably materialistic, he must perceive, if he only can take a reasonably long period into account, that the environment is only relatively materialistic, not absolutely nor unchangeably so. The environment assumes more and more the aspect of a conjuncture. And this must be so, since his life is continually becoming more psychic. As he learns to "annihilate time and space," his environment or conjuncture must itself become less material, since otherwise it would not preserve a fairly constant relation with him, and Nature's continuity would be broken. More action, more "annihilation of time and space," involve more active cerebration, a more mental life, and hence justify the general characterization of progress as "psychic."

Moreover, man progresses by a process of feeling his way, by a series of rebuffs administered by the controlling limits of the old environments. The successful experiments, however, become

fixed institutions and improvements. Further progress must either alter them or be based upon them. Consequently, a large part of the future advance is conditioned upon the results of past advance. Those results may themselves, however, in many cases be altered. Still the further back man goes towards the lower environments, in his efforts to change conditions, the harder will it be to alter the environment; the further forward he goes, the easier will it be, and consequently the more will he be master of his fate, *faber suae fortunae.*

In order to understand a crisis, the theory of progress must be understood; without it we can neither understand the peculiar nature of the crisis itself nor the gradual variations from a comparatively or short-time stato-normal condition that lead up to and away from the crisis. The crisis is an integral portion of industrial activity, and its phenomena are of the same laws and principles working within the same categories as are recognizable at each and every point of time.

Looking at a crisis now, in the largest way, from the point of view of the progress through successive environments, there is but one discovery that can follow our quest: the crisis marks the transition from one industrial environment or conjuncture to another. The crisis-process clears the way for reorganization and recommencement of activity within the new tentative environment or conjuncture. Looking widely over a series of years, it would seem as if this explanation was the simplest and fitted the most cases. The ninth decade (1880–90) of the last century witnessed the opening of vast further areas of the world's surface to settlement and to the market of the world. The Dakotas, the Argentine, and Russia were opened up. The crises of that decade were chiefly in confirmation or elimination of agricultural areas and held off greater disaster till 1890–93. The same decade also witnessed the opening of the mining regions of South Africa. After 1893 there was for a number of years comparatively little railway building. Industry of the tenth decade was busy living in and exploiting the new materialistic conjuncture which the previous decade had won. But a great new move towards further territory is now on foot. Reserved lands, like Oklahoma, have

been opened. Emigration to the Canadian Northwest has discovered regions to be attractive and fertile that were formerly deemed uninhabitable. But the principal territories that are to be added to the materialistic conjuncture of a new epoch are Africa, Siberia, and China. The Boer war clearly means the opening up of Africa to the world market. Whatever may be the reciprocal rights and wrongs of Briton and Boer, the utilities of man demand that South Africa be added to the world environment. The expeditions to Cuba and to Pekin may be "predatory forays," reminding us of the age of fist-law, but it is the destiny of the tropics and of the Orient to enter the world market *pari passu* with the development of railway and navigation. Wars like the Chino-Japanese are but incidents in the economic development. The economic and political relations of men must work within and throughout the wider environment.

The quasi-materialistic conjuncture displays notable changes: electrical inventions had something to do with the crisis of 1893. Electricity has been a most prominent feature and disturbing element of the subsequent period. The world of industry was by that crisis partially and only partially adjusted to it. It has been an especially prominent factor in the depression of 1901–02 in Germany; so that we have in electricity a case of slow development, but with continual surprises which makes it practically impossible for industry to know the limitations placed by the new invention upon new activity.

In steam-transportation, the new developments of the ninth decade were revolutionary, but those of the tenth were equally so. Greater power and capacity of old kinds of machines depend upon new inventions, especially those of new materials; but people only notice a change of kind and are surprised at great results where the change is apparently only one of degree. Twenty-five-thousand-ton ships and fifty-ton pressed steel freight cars tell the story of a new state of affairs that require larger plans and a more complex organization. Moreover, a new era of railway building is setting in; the Trans-Siberian railway allows of communication along its entire line, and the Cairo-Cape railway is under construction. The Panama Canal will soon again be

pushed ahead. Preparations are therefore afoot for a new and wider materialistic environment.

The psychic conjuncture changes with the materialistic, but not precisely *pari passu,* for it does not embody a complete visualization of the materialistic. The subjective reality is not of the highest type; otherwise there would be no crisis. It is precisely in the failure of complete correspondence, parallelism, or dualism, if you will, that exist the seeds of future crises. Thus, in the ninth decade of the nineteenth century, the immense expansion of the market fundamentally attributable to the stimulus of the Bessemer process, necessitated a correspondingly extended and more complicated organization. This was accomplished by the putting of allied interests into the hands of trustees for the purpose of carrying out a certain trade policy. This recognition of the growing scale of productive and distributive operations was quite justifiable and appropriate; but it was accompanied by a largeness of view as to the future possibilities of trade that was too elastic and volatile. While the magnitude of subsequent development was not and could not have been exaggerated, the error lay in thinking it would come too soon, and still more *in not allowing for quick changes* in the inchoate materialistic conjuncture that must intervene, and that might occur in any line of production.

Annihilation of space, economically considered, consists in the traveling of men or in the transporting of commodities from one place to another, in no time. Similarly, annihilation of time consists in apprehending a future environment without the more or less gradual space rearrangements and variations, mechanical, chemical, geographical that must surely intervene; in other words, it is economic prediction. It is precisely error in economic prediction that has always formed the characteristic of crisis conditions, and the eighties were no exception. Over-capitalization was the expression of this error, which, while it formed the principal theme of the fluctuating crisis process, was also so constant an element as to form almost a feature of the psychic conjuncture. There existed a constant tendency to overcapitalize (inflate or "water" the nominal capital); but the manifestation of this ten-

dency was extremely varied and formed a salient feature of the crisis process. The checkered history of the trusts, the investment companies, the land mortgage companies of the eighties—not to speak of the fluctuations of credit in a banking sense, and of commodity prices—were all part of a great socio-industrial attempt to adapt the psychic conjuncture directly to the more mobile portions of the materialistic conjuncture, while the latter was also not through with the work of adapting itself to the more fixed parts of the materialistic environment. The attempt, of course, was not wholly successful and the great crisis of 1893 followed.

The ground was cleared for a new psychic structure of organization and credit. The work went on slowly and cautiously. Complete liquidation was insisted upon so late as 1896. The absolute necessity of the largest possible scale of organization was well understood, and the public was constantly assured that all estimates of values were conservative. Doubtless an effort in that direction was made. But the steady and uninterrupted rise of prices, 1898–1901, and the continued capitalization of "trusts" in round numbers of incomprehensible amount tell the old, old story. There was, however, a distinct change in the psychic conjuncture between the periods of adaptation preceding and succeeding the crisis of 1893. The preceding period had been one of doubt in the industrial world as to the necessity and practicability of the larger organization. The post-crisis period, after the last liquidating wave of 1896, exhibited no doubt on this score. In fact, the long drawn period of depression and liquidation, 1893–97 (in fact, taking a broader world-view, 1890–97), was due probably to a consciousness of the magnitude of the task of reorganization, which was not to be undertaken lightly, and in an environment which was uninviting for small and hence quickly organized businesses.

If, however, the economic mind has fairly adopted the habit of large organization, the same can not be said of the political. What was true of the economic mind in the ninth decade is still true of the political mind: it is at a loss to accommodate itself to the new economic environment. It is from this fundamentally

economic and kinetic standpoint that explanation of political phenomena must proceed.

The crisis is thus the door between two economic environments. How it is such a door is only to be explained by reference to the kinetic industrial process. It is not true, as the static economics would assume, that the crisis is a mere sport that may never happen again, an impudent disarrangement of preconceived laws, which it is beneath our dignity to explain. The crisis is that moment when the manifestation of the accumulated little changes first occurs in full size; it is the supreme moment for the kinetic analysis. M. Clément Juglar says that the crisis *is* the end of the rise of prices.[1] The difference between these definitions is that between a broadly systematic point of view and that simply of the most important category in active manifestation.

## VII

### THE THEORY OF THE CRISIS
### (Continued)

### *B. The Process*

The pain of the crisis does not come from the general diminution of production[2] so much as from the rearrangement of individual fortunes. The process of liquidation, while it does not stop production, does reduce to zero or greatly decrease the rate of increase in production, which is one of the signs recognized by Mill and others as a test of economic progress. It is this personal inconvenience of the necessity of liquidation, therefore, that is to be accounted for. The simple principle of selection by the environment now stands us well in hand. As in all organisms, so in society, the larger controlling influences do not operate always by a gradual process of differentiation. While the idea of continuity and of continual development by infinitesimal differentiation is doubtless to be insisted upon as the more

[1] "La crise serait donc l'arret de la *hausse* des *prix*, c'est-a-dire le moment ou l'on ne trouve plus de *noveaux preneurs*." Des Crises Commerciales, p. 14, cf. p. 33.

[2] In 1884 and 1894 the fall in freight earnings and in iron and steel production was comparatively small.

refined and real and hence the more elusive, it is also true that Nature does also make decided breaks and apparent discontinuities. It is these discontinuities that affect principally the mind of man. It is his observation of them that forms the ground of his judgments and of his reality. It is precisely they that have trained him to be a reasoner by contrasts, a neglecter of the controlling forces. Volcanic eruptions and earthquakes are the occasion of vast loss of life, but are hardly to be counted as a part of the more fundamental geological processes; and similarly, crises are the occasion of a high financial death-rate, but they are not the fundamental causes of it. Earthquakes are necessary to restore an equilibrium that has been unbalanced by a strain upon the earth's crust, caused by secular deposits of detritus, and crises are necessary to force a liquidation really caused by the strain of personal obligation gradually accumulated by the process of progress.

It is generally agreed by serious students that "credit" is the chief category of crisis phenomena. Whatever be the favorite fads in the assigning of deeper causes, such as "overproduction," "lack of purchasing power," etc., all concede that credit makes the whole display at the final catastrophe. "Credit" is the popular term for the congeries of contracts that witnesses the individual relations of promise and guaranty between producers. These promises are an evidence of the stimulus, which, passing from producer to producer, causes a surplus. Through the intervention of the banking system and its guaranties, they are generalized as before described and become subject to independent management and direction. From the country and local banks they are collected into more central institutions and added to by the immediate contributions of the greater producers, until they reach the highest levels of finance. On these levels they are so detached from their materialistic origin that they do not react at once from the technical influences of the conditions of production. The great capitalists (who are the great debtors) form their own conclusions as to the future prospects of productive undertakings, and they encourage or discourage investment with a free hand. Thus it is that small variations in the technical

prospects of industry may create undue variations in the value anticipations of financiers, and to the fluctuations in technical production due to the vicissitudes of the conjuncture, the financial world adds greater fluctuations due to psychological causes. Enthusiasm for speculation finally gives out from sheer bodily fatigue. A slow market in stocks is ascribed to the fact that a prominent operator is taking a trip south.

The whole process is strangely analogous to what is known in electrical science as "resonance." Let materialistic industry represent the dynamo from which a current proceeds and to which it returns again. The current of credit carries its stimulus from point to point in the ascending psychic scale, at each point finding little reservoirs for storage, so that the current is not uniform at all points of the circuit, until finally, in the highest psychic part-environment, a sort of a "loop" is formed. Here, by means of coils of wire and a pair of Leyden jars, an independent current is induced from the principal current. In other words, not only does the principal current pass through the loop, but the loop has an independent current of its own which is so intense as in case of interruption to generate light rather than heat,—light being a phenomenon of a more psychic order than heat.[1]

In general the analogy of the action of the financial classes to that of an induced electrical current, even when it is entirely unconnected, is strong: the induced current does not start simply because the main curcuit in the field of which it happens to be is in action; it is necessary that there be some *change* in the main current in order to start up the induced current. Similarly, the world of finance is not capable of starting up a circuit of action on its own account; it must wait until *surplus production* has set in motion a larger quantity of floating capital and thus have charged the field with a stimulus of which it can borrow a part.

By a mechanism of this nature, periods of speculation begin to arise shortly after the disturbance of the industrial equilibrium or calm which marks the end of the period of liquidation. For

[1] I am indebted for this analogy, taken from an experiment of Tesla, to my colleague, Professor George Hart Morse, of the department of electrical engineering.

speculation to assume a perfectly even tenor would be a most unnatural thing in view of the mechanism described. Thus, after the crisis of 1882–84 we find the inception of a new speculative era over the whole world, except Austria and France. The year 1888 was not so brilliant; 1889 saw a perfect fever of speculation which culminated in 1890 in the preliminary crisis of that year. Then there was a calm for a year, attempted renewals of speculation in 1892 and finally, in 1893, the final catastrophe took place, with the United States and Australia as its principal theaters.

Fortunately the Austrian economist, von Böhm-Bawerk, has furnished us with a psychological theory of speculation which allows us to obtain a better insight into the action of the speculative mind in making its time-discounts. The general principles are the following: Anything enters into the present market in which people choose to trade and on which they put a value. The most common commodities besides present goods are future goods. That goods are not yet produced is no hindrance to trading in them, and in fact such trading is the common phenomenon known as credit operations. Now the value of the present and future goods in terms of one another must be such in the gross that the future product will be equal to the present product plus interest and profit. If the expectation of the gross future value is very large it will cause a high rate of interest, attract investment, and raise the price of present goods. If the price of present goods were not raised, they would be exhausted by the demand for them as means of future production, and a period of dearth would intervene before the future products themselves ripened into present goods. "Now the constant presence of the agio on present goods is like a self-acting drag on the tendency to extend the production period."[1] Of course if this warning of the rise in the price of present goods is not heeded, a catastrophe must ensue. The warning never is heeded; and this is undoubtedly the most fundamental cause of the crisis.

We would expect then that the rise in the price of stocks would be the first phenomenon following the return of industrial activ-

[1] *Positive Theory of Capital*, p. 335.

ity, and that this would be followed by a rise in the price of commodities. Stock-watering, however, while it would tend to conceal the test of stock prices, would itself be an additional proof of the first stage of over sanguine belief in the future.

When it is found that certain inventions or that a new organization of industry are probably to be productive of increased subjective values and hence of an increased rate of profit, there exist few present means for the ordinary man, at least, or even for the speculator to gauge the expected surplus. It is but natural, therefore, that these expectations should fluctuate with very little reference to actual materio-technical processes. The vast undertakings call for present goods, and as the latter become scarcer and less and less available for immediate consumption, their prices rise inordinately. The more prudent financiers restrict their operations. The less responsible push forward new stock-watering combinations in the hope of standing out from under before the failure of their schemes.

The very first issues of stocks and bonds are steps in the mechanism of the credit and guaranty system. Just as, in the fields of business that lie closer to materialistic production, producers' promises are exchanged for bankers' promises, which the public receives on the bankers' guaranty primarily, so in the highest psychic conjuncture, the enterprises that are started by financiers are "financed" and guaranteed by combinations of underwriters, consisting of other financiers, of banks at the financial centers, of international banking houses, of trust companies, etc., who guarantee the organization and launching of these enterprises as going concerns. In fact, we read of one set of underwriters needing another set to guarantee them.

In confirmation of this theory, the recent course of prices may be consulted. The rise in the price of railroad stocks and the increase in bank clearings was very marked in the financial year of 1897–98 and continued rapidly during the next two years. The average price of all commodities rose a little in England and the United States in 1897–98, fell a little in the United States in 1898–99, and did not finally take its upward trend till the year 1899–1900. The characteristic commodity, iron, continued to fall

during the years 1897–98. In 1898–99 it rose a little, and it was not until 1899–1900 that it took its great upward soar. The metals as a whole did not rise at all until 1898–99 and railroad freight rates did not rise till after 1899–1900.[1]

Of course, disproportionate production (partial overproduction) may have some influence in causing crises. Doubtless some producers find to their sorrow that they have miscalculated the market, but in general it is not in this direction that we must look for the cause of widespread failure. It is hardly probable that if the laboring classes are receiving less pay, producers would keep on producing the same amount for sale to them, as one theory maintains; and the same is true of overproduction along other lines. It is not necessary in order to cause a crisis that the final products of industry should be so disproportioned that they would not be salable against one another, were the conditions of personal obligation otherwise static. It is the fact that the great productive organizations have promised more than they can carry out in the way of returns to investment which is the great cause of crises. This analysis offers the explanation of the abnormal credit,[2] which characterizes crises.

When at last the exhaustion of present goods reaches an acute stage, and the inability of the new concerns to make good their promises becomes manifest, all hands turn attention towards liquidation. The whole structure of stock, bond, and note promises becomes valueless, and to a large extent even for the purposes of set-off. Stocks and bonds can not be set off against stocks and bonds in payment of debt, for they are not negotiable; nor can individual notes be set off against each other, for since they have become generalized in the form of bank credits, the holders of notes against each other can not be brought together nor would they accept attornment if that were possible. In other words, the public holds notes and accounts against the banks, and the banks hold notes against individuals; but the public will not accept the private notes held by the banks, but demands fulfilment of the

[1] *Bureau of Economic Research* (Ed. Professor John R. Commons), No 1, July, 1900. Diagrams, pp. 30–34.

[2] Professor J. Laurence Laughlin, "Credit," University of Chicago Decennial Publications, secs. 6, 7.

guaranty by payment of coin. Bank notes are not accepted, since they are founded upon the unproductive stocks, bonds, and private notes. The consequence is that the market for future goods is wiped out as with a sponge, and the exaggerated demand for present goods is at last turned specially towards one of them, namely, the real money of liquidation contained in the guaranty fund—gold. Other goods now drop in value and the one good, gold, acquires an unusual importance.

From the conjunctural point of view, the inordinately high price of present goods indicates a tendency towards a lower environment. While future goods are still in the market, just before the crisis, they are inordinately depressed below present goods, so that the prominent contrast in the market is the relation of future to present goods. The exchange value of future goods is so depressed that no possible technical increase in their output can compensate for the fall. The market being resolved into an exchange of present against future goods, the high value of present goods is discovered to be all in terms of promises. This is inflation pure and simple. The visualization of the market by the current theories has treated promises materialistically, as so much wares, commodities:

"His" (the holder's) "cession of property" (in a note) "by sale" (to a banker) "is as distinct and complete as if he had sold a bale of cotton to another merchant."[1]

"Here then" (deposit), "as in the former case, the transaction is in effect a sale, although the use of the word 'deposit' seems at first to justify an entirely different idea of its character."[2]

The market takes the will for the deed; it obeys the maxim of equity to "consider that as done which ought to be done." So long as negotiable paper is regarded as good, it does not need to be paid. Without ever being paid, it is always treated as though it were paid; and so it continues, by renewals and replacement with new paper, to perform the high duty of circulating goods for an indefinite period. But when it is evident that the promises can not be fulfilled, then one side of this equation, present-future,

[1] Charles F. Dunbar, *Chapters on Banking*, 1st and 2d ed., p. 11.
[2] *Id. ib.*, p. 14.

falls away, and the market for future goods vanishes. The general market now deals in a new commodity, gold.

Everybody in the community that had any surplus had calculated on too great returns from it. Laborers had calculated on too high wages. The whole society had anticipated an inordinate increase of subjective total values, and this had influenced them in incurring all sorts of expenditures on present goods at a high price. Business corporations had incurred heavy bonded indebtedness on the basis of high returns. But the rise in the exchange-value of present goods inevitably engenders a rise in wages—one of the largest expenses in most businesses. Critics discover that corporations, on the face of their published statements, are carrying insufficient reserves or surpluses for necessary betterments and replacements of old or antiquated plant; boards of directors issue additional bonds for improvements and thus create additional demand for commodities in terms of future goods.

In the early days of the credit system, it was supposed that inflation took place because inconvertible notes could not be presented for money when their value fell.[1] With no more than normal renewals, or, in other words, with normal payments into the bank in discharge of borrowings, the bank notes could hardly suffer very serious depreciation from the mere lack of convertibility. In the absence of lack of confidence, payment into the bank in discharge of debt would act the same as presentation for redemption in keeping up their value. Excess of issue is clearly the cause of depreciation in such a case. Since all issue arises from loans, excessive issue can only arise from a too high valuation of the security or of the product. Productive loans are made on the expectation of production and nothing else, and their nominal value can rise only with the nominally greater productivity of the process. In other words, inflation is exaggerated forecast of productivity.

The persons directly responsible for mistakes of this sort are chiefly the leaders of financial industry. It would, however, be

[1] "But if by law they (the bank notes) are not so convertible, of course this excess will not be brought back, but will remain in the channels of circulation, until paid again into the bank itself in discharge of the bills which were originally discounted." *The Bullion Report 1810*, Sound Currency, vol. II, no 14, p. 20.

an egregious error to mark them out as solely responsible for credit fluctuations. The financier is but a leader, not an autocrat. He is powerless without cooperation. In order to secure this, he must offer sufficient inducements. If the bonuses, the capitalization of prosperity-income, of good-will, bring on inflation, is that more to be laid at the door of leaders of finance than of the investing public which refuses to join the procession of progress without such inducements? The financiers are the prime movers in progress, but they can only act within and through the existing conjuncture. The largest concerns are those that set the example. The induced currents of "credit" acquire a high tension in the independent circuits of high finance and are finally discharged through optional connections with the primary circuit, or even across non-conducting spaces. The whole industrio-financial body is finally coerced to join the movement upwards, on principles of normalization familiar to students of society; all prices are forced upwards in order to meet the rising tide of expense. Laborers, common carriers, hotels, as users of the prime necessaries produced by the corporations, put up prices in order to cover their rising expenses. The most striking example is offered of the all-compelling power and irresistible action of the social mind.

In recent decades, covering as they do a series of successive environments, exchange has normally been effected on the credit plan. The movement towards the crisis has consisted in an exaggeration or abuse of that plan. The definition of credit as "set-off" makes prominent the simultaneous or spatial feature. Along with this goes a temporal feature. Normal credit is not only of a certain standard value but it represents a normally long production process. Credit must exist of a certain *length* in order to allow those transportations of merchandise from place to place which are necessary in order to fulfil physically operations of sale and delivery. When delivery is effected, set-off may occur. It can not occur sooner, for the flow of bills can not, on the average, be faster than the flow of goods.

Similarly, payment of loans can not occur faster than production turns goods out. The roundaboutness of the process limits the length of the promise, on the one side; distance and rapidity

of delivery, on the other. Accordingly, there exist two kinds of credit, one which lengthens with the roundaboutness of the process, and one which shortens with the rapid delivery of goods. The latter is the more spatial and the more employed in set-off; the former the more temporal, and the more presented for liquidation. But they are intimately allied: if the temporal credit cease to exist, production ceases; there are no goods for sale, hence spatial credit ceases also. Either kind of credit affects the general level of prices. Mere bulling of the market for certain goods, say iron, may cause an inflation. But the usual and more potent cause of inflation is to be found in the temporal credit connected with the launching of industrial enterprises. This sort of credit most powerfully affects prices. So far as mere exchange is concerned, of course, the level of prices is of little significance. So long as goods are produced, the set-off system can operate, for it is purely a matter of exchange, and the static philosophy teaches correctly that the number of counters employed in exchange is a matter of indifference.

This is the normal, dual, time-space mechanism of credit in recent environments. The lengthening of the time-norm lends to them their psychic aspect. With onward rush of credit-stimuli, marked by pauses and renewed currents of ever greater intensity, a disproportion of the stimulation of credit to the productive capacity of technical apparatus and, in a less degree, to customary consumption, ensues. There is a hypertrophy of the nervous system of industry. The main result is a general fall of future values. They finally cease to be dealt in. This is a painful matter for the persons chiefly interested in them. Having cast in their economic lot with speculative production, they must now pass through a process of liquidation corresponding in severity to the disapproval which their enterprises may have met at the hands of the general conjuncture. Nor can anyone escape some share in the general liquidation; the principle of the social mind is again invoked. The most conservative citizen, the one least implicated in speculation, finds his property unsalable. Income is equally affected, since income is only realized through exchange. The exchange process, which is assumed to run itself in many

orthodox theories, such as the proposition that a man produces his own income, now takes full possession of the economic scene. How to set exchange in motion becomes the great problem of the hour. A halt is called for liquidation, while persons who hold titles to property, such as land or goods, must hold their breath, as it were; they are lucky if they obtain daily necessaries and pay taxes. The period of decline asserts the social solidarity with even more emphasis than the period of inflation. The rich are in mental distress, while levelling agitators find ready ears among the half-employed poor. It is remarkable that so few are in a position to take advantage of low prices in a time of crisis in order to speculate.

There is a partial reversion toward a lower environment, or at least conjuncture. The leadership of the psychic classes has failed; the extended processes have not come up to expectation; the rate of profit on the actual investment, while high, is not sufficient to pay a normal rate on the mass of stock-water. It may be said that the amount of stock was an experiment in the field of psychic conjuncture. When put to the test of the materialistic conjuncture, the experiment fails. New companies must be formed on a basis of stock compatible with the returns actually experienced or old companies pass through a painful reorganization, involving a scaling down of stock and bonds.[1] When the new concerns are formed, there exist the conditions for a new period of prosperity; but the scaling down of stock and bonds has been a drastic operation. It must not be thought that there is an actual standstill of production during liquidation. Most concerns continue to produce, upon reduced scale and in the hands perhaps of court receivers. The great mistakes have not been those in technique, nor even those in anticipation of relative demand and relative consumption (as is claimed by most theories in the face of the very patent fact of a general liquidation), but the mistakes of the quasi-independent psychic classes in failing correctly to forecast total social values.[2]

[1] Edward Sherwood Meade, *The Reorganization of Railroads*, Annals of the Am. Acad. of Pol. and Soc. Science, vol. XVII, p. 205.

[2] Besides the writings of Patten and Clark, *passim*, cf. the writer's *Values, Positive and Relative*, Annals of the Am. Acad. of Pol. and Soc. Science, vol. IX, no. 1, p. 81 sqq.

The unlocking of hoards, the importation of gold, and its frequent use in transactions and in financial centers where the highly developed stato-normal credit system had entirely dispensed with it outside the guaranty or reserve fund, characterize the period as one of lower psychic tone. On the other hand, these periods of reverses are not simple, direct retrogressions. The instruments of the earlier environments are used for the distinct purpose of clearing the ground for a new advance. The temporary regress is merely a device in the grand plan of progress. The psychic credit system preserved the *guaranty fund* down from the days when money was the sole medium of exchange for the express purpose of avoiding complete repudiation and disarrangement. By means of it, individuals are enabled to make good their promises, but slowly and at sacrifice. Abnormally low prices evidence the same helpful conditions. They encourage the use of gold and help on liquidation and the starting afresh with individual obligations more in accord with the technique of the materialistic conjuncture.

The lowest level of prices is reached in those communities where gold imports do not penetrate, owing to poverty or to a chronic state of indebtedness. In those communities there is no accumulation of wealth that can be used to pay debts or to purchase gold. They are accustomed to transact their current business in the evidences of indebtedness arising within wealthier communities. Lacking these, they must perforce fall back upon barter or extemporize a local currency of their own.[1]

The expression "overcapitalization" is used in two senses, that of stock-watering and that of too large a proportion of fixed compared with circulating capital. Confusion of these terms is not greatly to be wondered at, since the practice of the former encourages the latter: the attempt to create great profits leads to a too hasty conversion of present into future (capital) goods, thus raising the price of the former, as so well described by von Böhm-Bawerk. Some writers have gone off on a side track: they ascribe the fall of profits to the "competition of capital," and explain the conquest of wide markets as an attempt at compen-

[1] John De Witt Warner, *The Currency Famine of 1893*, Sound Currency, vol. II, no. 6.

sation. Doubtless low profits often drive producers on to plunge deeper into production; but there is nothing inherent in the "capitalistic system" to produce this effect. The lack of proper adjustment of the psychic to the materialistic conjuncture is the fundamental cause, a cause that is deeply implanted in human nature, far deeper than political policies; and from this evil even the socialistic state could be free only on the hypothesis that it had wiser leaders than those that now are found within the psycho-financial circuit, or on the other more probable hypothesis that the socialistic state did not advance at all.

The retirement of the psycho-financial classes after the crisis, and their preoccupation in the inter-adjustment of their obligations, amounts to a total withdrawal of the reenforced and reactionary stimulus which they had supplied to industry. This must now jog on for a while, as best it may, with merely the stimulus of the simple, primary current; and while there is not probably any great reduction in the total mass of production, below at least the recent average, there is a decided falling off in those industries that have recently been especially favored. Thus, from 1883 (crisis) to 1884 the tonnage constructed in English shipyards fell from 892,216 to 588,274 and even to 331,528 in 1886.

The essential features of the theory of economic crises are:

I. Crisis phenomena are normal and kinetic. Their proximate causes act in obedience to laws of motion and change. A thorough study of crises will give to laws of that character a much greater prominence in economic theory than they have hitherto claimed or attained. It will be recognized that the theory of the state of progress is as important as the theory of the stationary state. The latter theory, however, is necessary to the former. In order to apprehend a law of change, we must first crowd into a given space of time as many stages as possible, each of which momentarily presents itself as stationary.

II. Since economy is the satisfaction of wants, it consists in the furnishing of relatively material objects for the use of a relatively spiritual subject. Consequently progress must consist in an elevation of this relation in the psychic scale: the subject and the object must both become more psychic, while preserving

their mutual relation. The laws of progress must explain the general movement upwards as well as coincident modifications in the relation of subject with object.

III. Progress may provisionally be described as a journey from house to house, or from environment to environment of a progressively cultured or psychic character, i. e., adapted to psychic advance of man. The lower environments are materialistic; in them man must conform himself very strictly to materialistic conditions. The higher are psychic; in them man conforms himself to conditions predominantly psychic. Since the latter conditions are dependent upon himself, he may create or even alter them, if he will but make the necessary sacrifice of time or consent to retrace his steps temporarily.

IV. In a normal course of progress, free from retrogression, both the materialistic and psychic conditions present a permanently environmental character. They are long-time causes, changing little. Such change as does take place in them may be compared to the change made annually in the volume of coined money by the mintage, while the mass of the coins have been in circulation for decades, and some individual coins may be made of gold taken from the mines of Philip of Macedon. The materialistic and psychic parts of an environment may, for convenience, be treated separately.

V. In the higher environments change is rapid, and new conjunctures swiftly succeed each other. The process of change may here be seen weaving the conjunctures within which it will continue its work. A complete treatment would describe the assimilation of conjunctures into the environment.

VI. The process of progress must be such that it can occur within the existing environment, including in that term the existing conjuncture. The environment being partly material and partly psychic, the process avails itself of the contrast and of the continuity between these two economic elements.

VII. Our own nature is such as to render it probably impossible for us to apprehend any process except with the aid of at least two sets of analogies: those of physics and those of biology.

VIII. The physical analogy suggests primarily the laws of the changes in industrial equilibrium. The concrete movements that take place in the industrial relations of different geographical areas, classes, products, and businesses, and in consumption, may here be described with a view to ascertain the order of their adjustment and readjustment to each other.

IX. The biological analogy suggests primarily the laws of stimulation. These laws are fundamental to the process, for they determine the disturbances in industrial equilibrium. They can only be rightly apprehended by a thorough revision, in the kinetic sense, of the theory of credit. The conception of credit must be reduced to its simplest terms in the business man's promise. It will be found that promises are made coincidently with the saving of surplus goods, and that they act and react in waves and cumulatively upon business and industrial progress.

X. The crisis is a normal exhibition of the culmination of the stimulative process. Its theater is the market: the culmination of stimulation suspends abruptly the part-market for future goods, which usually is the more important; the part-market for money now endeavors imperfectly to fulfil both the demands upon the market for future goods and those usually made upon itself also.

XI. From the environmental point of view the crisis is the door between two conjunctures. Those industrial experiments are eliminated that do not harmonize with the new conjuncture.

XII. The crisis process is one of social solidarity; it is a general movement all along the line; it is not, in its essence, an overproduction of goods, but an overproduction of promises.

## II.—*On the Validity of the Ergograph as a Measurer of Work Capacity*

### *A Contribution to Practice and Learning*

BY THADDEUS L. BOLTON AND ELEONORA T. MILLER

### INTRODUCTION

The purpose of the experiment discussed in the following pages was to test the validity of the ergograph as a measurer of the capacity of an individual for muscular work; that is, to determine in how far the ergograph records might be relied upon as giving a fair estimate of work capacity. The chief consideration in this, as in any psychological problem where it is a question of measuring processes accurately, is to determine the probable value of a single observation or small number of observations made within a few days, as furnishing sufficient data upon which to generalize. The treatment of this question in connection with the present problem involves a consideration of the character and direction of influences which are most likely to affect a single record or group of records, and thus render this record or group of records unreliable as an indication of work capacity.

Thus stated, the problem becomes a study of the variations that take place in a series of records taken under reasonably uniform conditions. Investigators have used the ergograph upon children and adults upon the assumption that a single record or a small number of records taken within a period of a few days is a fair measure of the amount of work they can do, and in the long run can be relied upon in a comparative estimate of the individuals studied. Are there not influences operative in a single test or a small number which do not affect a long series, and likewise, influences operative in a long series which do not enter into a single test? Do records change relatively in the course of a long series so as to invalidate those at the beginning of the

series? Are records taken after practice a better test of work capacity than earlier ones? These are a few of the questions which present themselves in a study of this kind, and for which answers must be found before tests of capacity can be regarded as trustworthy.

Ordinary circumstances do not mean the same for all people. Normal daily life and habits keep some individuals nearer than others to their maximum capacities all the time, so that a short series for the former would more nearly represent the maximum; while, on the other hand, those whose bodily conditions resulting from daily habits keep them near the minimum of capacity would not, in a short series of observations, reach a point even approximating their maximum capacities. Accordingly, the maximum records must be used as the standard, and this makes it absolutely necessary that the reagents be practiced in the particular exercises used as tests.

Upon empirical grounds it is highly probable that practice is an essential in many psychological and physiological experiments before the tests have either relative or absolute trustworthiness. If ordinary circumstances meant the same thing for all individuals, it would not be necessary to go through long and severe courses of training, because tests at any time would establish the relative merits of each, and, furthermore, it is probable that certain individuals are capable of far greater practice effects than others, so that the relative merits can be determined only after each has been brought to the highest level of practicable practice effect. Accordingly, maxima of effort are used by all trainers of athletes and by sportsmen and breeders of animals when comparisons of relative merits are made. But besides this there are other reasons why maxima should be sought for. First, there is the purely sentimental one of knowing how great a performance one is capable of; and, second, the reason that in performances where accuracy is the chief desideratum, as in marksmanship, relative estimates are entirely without point until a certain degree of accuracy has been obtained.

In nearly all skilled occupations the maxima are demanded for commercial reasons. In many occupations workers can not

obtain a livelihood until they have attained considerable skill. Without practice they can not do anything at all. The training to which race horses, prize fighters, and professional athletes must submit before they enter contests is essential both from a sentimental or sporting and commercial standpoint; they must be made to reach the highest level of practice effect of which they are capable in order to satisfy our pleasure in seeing animals and men contend and strive with one another in rivalry and because the strength, skill, and agility developed in this way come to have commercial values as they formerly had selective values in biological history.

*Empirical Observations upon Practice.*—Practice is not a simple phenomenon; it manifests itself in different ways. One may easily discover a variety of effects which exercise will have upon the individual who practices himself in any line with vigor and persistence. Naturally the results are not the same or uniform in degree. Certain effects are greater and more obvious in one kind of work than in another. The first and probably the most important condition brought about by exercise is *inurement* to the task. This is a process of hardening whereby the tissues and skin which at the outset were rendered inflamed and bruised by the physical exercise become calloused and give rise no longer to the painful sensations which were experienced during the first exercise. Want of inurement results in a greater or less degree of muscular soreness and stiffness. A single unusual exercise of any kind, if it be at all violent, has this effect. This soreness and stiffness are probably due to small lesions of the tissues through the rubbing and twisting of muscular and tendonal fibers about one another which are followed by local inflammations. Lagrange[1] attributes this condition to the retention within the muscles of obscure waste products. A different hypothesis seems to us more probable. The muscles and tendons lie contiguous to one another in the members and when their positions remain unchanged toward one another for considerable periods, as they do at times when exercise is not taken, adhesions grow between them as in all other tissues. Now when exercise is taken, the

[1] Physiology of Exercise. Appleton & Co.

muscles and tendons change their relative positions, and in that way the adhesions are broken. Continual exercise is necessary to prevent them reforming. The rupturing of the adherent tissues produces local inflammations which are felt as soreness of the members. A very small amount of exercise will prevent the formation of adhesions. Other conditions follow a want of sufficient exercise. These are the growth and deposit of fat in and around the muscles and the development of a flabbiness of the muscular tissues themselves. These can be checked only by vigorous and systematic exercises regularly followed up. In games and gymnastic exercises such as basket-ball, jumping, ladder-climbing, etc., the painful sensations persist for some days, and the exercise must be kept up vigorously until the muscles and tendons become hardened, that is, until the inflammation from the rupturing of adhesions and blood vessels in the sheaths are healed and callouses are developed where the rubbing is severe and persistent. The training of prize fighters and athletes is first of all, then, a process of hardening and toughening during which all the muscles and other tissues of the body share in the development which renders them less liable to injury. This is a physiological and not a psychological process. The disappearance of this muscle soreness is not to be attributed to our becoming used to the discomfort and hence not noticing it, but to the fact that the conditions that gave rise to the painful sensations cease to exist.

Secondly, practice results in acquisition of more or less skill and agility in the performance of a movement; that is, one has a better knowledge of the movement and is capable of more ready execution. From the physiological point of view skill is growth in the perfection of muscle coordination, and it means not only proper coordination, but certainty with which the coordination can be repeated successively and without variation. A greater or less degree of awkwardness characterizes movements made before practice, that is, there is superfluous and misdirected activity. Before practice we do not know how to apply the power at the point where it will be most effective; during practice there comes about a reduction or suppression of superfluous and extra-

neous movements which are energy-consuming and use up the force that should be exerted in other directions. This subject will come up again later. When all the muscle groups work together for the same end, the performance of the movement is said to be skilful. The difference of manner in which the skilled and the unskilled bicycle rider "take a hill" is due to the way they apply power to the pedals. The ability to throw the weight on the pedals at exactly the right point and at the right instant, and to make the proper movements with the other limbs and trunk characterizes the skilful rider, and the inability to time movements and apply power properly is the defect of the unskilled rider. In the game of golf perfect coordination of the muscles is essential. It is not always the most powerful stroke that sends the ball farthest, but it is the swing of the driver which takes the ball exactly at the right angle. Such a drive depends upon the success with which the player contracts all his muscles at the right instant and applies them exactly to the point where their combined effect will be greatest.

Thirdly, by practice the power or contractile force of muscle groups is greatly increased. After practice greater power is shown by the baseball pitcher's arm. This is due not only to an increase in the bulk of tissue resulting from increased nourishment through practice, but also to increased power of the nervous system to discharge in a definite way and to concentrate all the force upon a movement in a given direction. The muscles grow in contractile power, and the nervous system shows increased tendency to confine the nervous currents within narrow pathways. A given stimulus concentrated upon a few muscles will yield a stronger contraction than the same stimulus spread over a less definite area. Just as, when shooting at a target before practice, the shot is scattered over the whole target, so the nervous stimulus sent to the muscles in the first instance is distributed more or less widely, and as more of the shot will probably fall around near the center than towards the edge of the target, so the main part of the nervous excitation reaches the desired muscles; but during practice the nervous discharge comes to be confined almost entirely to the few muscles whose contraction is desired.

The accessory movements which contribute nothing to the performance and are energy-consuming gradually drop out.

Fourthly, practice increases endurance. By that we mean the power to contract a muscle a greater number of times under given conditions. Let us suppose stronger innervation reaches a muscle from a given discharge in the nervous centers after practice than before, and that the amount of energy-yielding compound in the cell presumably increases with practice, a greater number of successive contractions are rendered possible before the muscle becomes exhausted. The prize fighter, the football player, and the soldier are enabled to stand violent exertion for long periods of time by gradually increasing the amount of work as they grow in practice. Each increase in stint of work adds an increment to the available energy in the nerve and muscle cells at the disposal of the organism, so that the number of successive efforts may be greatly increased; that is, they can be repeated more often.

Fifthly, with the acquisition of skill movements become more rhythmical. The characteristics of rhythmical movements are the perfect interdigitation of a number of movements into one another and the joining of them together in serial order so that the first movement in the series shall become the stimulus provoking the next of the series, and these in turn provoke the next, and so on until the cycle is completed. The last element of the cycle becomes the stimulus for initiating again the first of a new cycle. A rhythmical movement then consists of a number of reflex actions following one another in serial order. The action of one is the stimulus for the second, the action of the second the stimulus for the third, and so on. Rhythmical movements differ from the ordinary serially coordinated movements in the fact that each movement of the series furnishes stimulus for eye or ear and sometimes for both, and the new movement or cycle is initiated from the special sense organ. Dancing is the type and is chiefly directed by the ear, for rhythms appeal most strongly to the ear; in fact, hearing is the rhythmical sense. The tendency is for all forms of work to assume the rhythmical type.[1] All nervous activity is rhythmical, the lowest centers following simple rhythms and the highest more complex.

[1] Bücher, Karl, Arbeit und Rhythmus. Leipzig, 1902.

So much for the positive phases of practice effect. Of the negative effects we may mention, first,—that acts which have become habitual require less voluntary effort for their performance than unfamiliar movements. When an unskilled bicycle rider tries to ride up hill he must have his attention upon the task constantly, and the mental strain is very noticeable. After practice the task is accomplished better without conscious direction. Secondly, distractions are less likely to draw one away from work in which one is well practiced. Telegraph operators who are new at the business are bothered very greatly by the other sounders when they are obliged to work in a room with many operators. But with practice they can listen to the click of their own sounder and are not disturbed by the confusion about them. Thirdly, voluntary effort usually becomes less irksome with practice. The feelings of weariness and tiredness intrude themselves less and less, and in case the routine does not become monotonous, we come to enjoy the task which we dreaded at first on account of the disagreeable results attendant upon the performance. After one is inured to the work and is accustomed to the machine, as in the experiment with the ergograph, there is enough novelty about the investigation of new problems to make the task enjoyable although the same old movement is performed day after day for weeks together. All the foregoing statements are based upon ordinary empirical observation; but before they can be considered as scientifically established it is necessary to study these phenomena under uniform conditions and circumstances which can to a great extent be controlled.

*Physiological Considerations.*—On the side of the organism, changes resulting from exercise can take three possible directions: 1, Changes in the muscles themselves which are exercised; 2, changes in the nervous control of these muscles; and, 3, changes in the blood supply for both muscles and nerve centers.

The changes in the character of the muscles will, as we have described, be a hardening and toughening of the muscle sheaths, rendering them less likely to become inflamed through the rubbing and twisting which they undergo during contraction. The

muscle fibers increase both in size and in contractile force. It is not known whether new muscle cells or fibers actually develop in the arm of the baseball pitcher or the blacksmith, but there is an enormous increase in size which may be due only to the enlargement of the muscle fibers themselves, but a simple enlargement must be accompanied by a multiplication of nuclei at least. It is probable that after exercise under a given degree of nervous stimulation the muscle will contract with greater force. There is an elimination of fatty and other superfluous tissues which hinder the contraction of the muscles and so decrease the resistance within the member itself. Also, there is less friction in moving joints, and tendons slide more easily upon their bearings as a result of the callouses that develop on them.

In the nerve centers controlling the muscles changes no doubt take place. From Professor Hodge's experiments upon nerve cells we learn that the energy-producing compounds are broken down during functional activity, which is indicated by a shrinking of the nucleus. This follows the normal daily activity of the nerve cells as well as electrical stimulation of them. During repose and sleep these compounds are again rebuilt, and it is probable that the anabolic level to which they rise is higher after exhaustion than before. Each exhaustion seems to add an increment of energy-producing substance above the usual level to which rebuilding rises. Again, as the result of further activity, the catabolic changes may be carried to a point lower than before, from which full recovery is possible and speedy, so that in the center which is properly exercised the limits of metabolic change are increased at both extremes. Thus it is possible, on the theory that each discharge of the center destroys an equal amount of the nervous compound, for the center to discharge a greater number of times as a result of practice. Permit us to offer the further hypothesis that a given discharge in the center will, on account of decreased resistance, send out a more intense impulse over the nerve fibers. This would make it possible for a weaker discharge to accomplish the same result, and thus exhaustion of the nerve center would go on more slowly. Recuperative processes between successive discharges would become

more rapid, making less the actual loss from each discharge. The cumulative effects of the discharges in a long series would be much slower in reaching the point where further functioning would be impossible.

Changes in the character of circulation in the muscle take place as a result of exercise. It is a well-known fact that activity in a muscle increases immediately the amount of blood that flows to it, and it is probable, further, that systematic and continued exercise will increase the possibilities for the amount of blood flowing into the muscle. Capillaries may be enlarged and thus the tissues will be washed by a greater flow of blood, insuring a more rapid elimination of the waste products accumulating through exercise, and at the same time furnishing a greater supply of oxygen to carry on the process of combustion within the tissues. Therefore during the interval between each successive contraction, the accumulated waste will suffer a greater reduction in amount, and more extensive rebuilding of the protoplasm will take place. For this reason the muscles may make a larger number of contractions before the waste products accumulate to the point where they have a paralyzing effect on the muscle tissues, and through the rebuilding of the tissues a larger amount of protoplasmic substance remains at the disposal of the muscle, from whose disintegration the energy for the contraction of the muscle is supplied.

The nerve centers, too, probably enjoy an increased circulation as a result of their continued activity. The accumulation of waste products in the centers will thus be kept down below the toxic point for a longer period, and the recuperation of the cells between successive explosions will more nearly equal the amount of exhaustion occasioned by the explosion, so that a large number of explosions are made possible before the point of paralysis is reached.

The lower nerve centers are automatic and recuperate completely between successive discharges, so that they can go on throughout life with no cessation of activity; they enjoy comparatively few and slight accelerations and suffer few and slight depressions. Nerve centers with regard to rhythmical activity

form a hierarchy, the lowest being perfectly rhythmical and automatic, the highest are the least rhythmical, or, at least, their rhythms are highly complex. Between the extremes of perfect automatic action and occasional activity we find all degrees of automatism. The heart centers, for instance, work most automatically of all, and the centers controlling respiration only slightly less so. The centers controlling the movements of walking possess a still less automatic character. They may continue their periodic activity for a number of hours with no change; but the time finally comes when the accumulated waste products within them are so great and the degree of exhaustion falls so low as to inhibit any further activity. They must then rest and recuperate, after which it will be possible to act again. It is not too much to say that they can continue in rhythmical activity for ten or twelve hours, this often happening in case of forced marches, when soldiers keep a uniform pace from morning until night with scarcely a rest. Of course a long period of activity must be followed by a correspondingly long period of rest in order that the nerve centers may recuperate. For normal daily activity of these centers the normal period of sleep is sufficient to restore fully the nerve cells. The centers for the control of the arms are less automatic than those that control the lower limbs. The periods during which they can act automatically are much shorter, and rest and recuperation must come more frequently. The normal period of sleep is not sufficient for the full recuperation of arm centers, so that rests must be allowed during the course of their daily activity. There are probably great individual differences in this respect. Sailors and expert oarsmen have been known to row continuously ten, twelve, and even fifteen hours. The highest centers of the cerebral cortex seem to show the smallest capacity for automatic activity. A center which is active in the conscious perception of an object must rest for a considerable time while another falls into activity in the perception of a different object. Thus consciousness shifts from one object to another, which means that the different centers act successively. Indeed, it is questionable whether a cortical center ever acts in successive moments in exactly the same

way. The effect of practice is to increase the power or capacity for successive discharges so that practice for nerve centers serves to emphasize the tendency to automatic functioning.

To sum up, in the most automatic centers recuperation is rapid, and in the least automatic it is slow. A period which is sufficient for the recuperation of lower automatic centers will not suffice for the higher centers. The effect of practice upon the higher centers is to render them more automatic, to increase their capacity for recovery, and to make possible explosions which are successive and repeated at short intervals.

## EXPERIMENT

The particular purpose of this experiment can be definitely stated in the form of a question the solution of which has been attempted. Can the ergograph be used as a measurer of work capacity; and, if so, under what conditions and within what limitations will its validity be greatest?

Surely the greatest source of error will be found in the lack of acquaintance which the reagent has with the instrument. No apparatus has as yet been found which is so simple that it does not require a certain amount of practice on the part of the reagents to be able to use it with good success. The chief reason for this is that simple pieces of apparatus give such enormous accidental variations that it is practically impossible to obtain results which have any claim to trustworthiness. More complex pieces of apparatus, on the other hand, require considerable practice before they can be used at all. Any piece of apparatus must then be a compromise between the most simple and the very complex. The aim must be for simplicity of construction on the one hand and for constancy and accuracy of measurements on the other.

The ergograph which was used was a modified form of the pattern designed by Doctor Hoch in Professor Kraepelin's laboratory. While it is a great improvement upon the Mosso instrument, it scarcely meets all the theoretical objections that have been brought against all ergographs. No instrument has or ever can, probably, measure all the work the reagent does. The best that we hope for is that the record will be a constant proportion

of the work that the reagent does at each trial and hence may be used to represent the actual work done.

The present apparatus has followed the usual method in ergographs in employing the contraction of the middle finger, but, contrary to the usual custom, it allows the use of both hands. The hand is laid in pronation upon a board, and the contraction of the finger is made downward over the end. The first and third fingers are inserted in stalls and the hand, from the knuckles back to the wrist, is held in a plaster-of-Paris cast which is moulded over it. The arm itself is strapped down in two places. The finger is inserted in a stall which can be adjusted both as regards size and length of the finger. The point of attachment for the weight is the same distance from the knuckle joint for all persons, the adjustment for length being made at the end of the finger. The finger is contracted downward, lifting a weight which is caught at the limit of contraction by a ratchet formed by a small steel ball that rolls on the grooved circumference of a cylinder under a dog, and the finger allowed to relax freely. The arrangements as regards the fixation of fingers and hands are in general new. The reagent remains standing during the test, occupying different sides of the instrument when the different hands are tested. Two views of the instrument and reagent are given in Plate I.

The weight used by one reagent was 6.84 kgs. and that by the other reagent 3.58 kgs. The latter weight, however, had to be increased toward the end of the experiment owing to the great practice made by the reagent and to the limitations of the apparatus.

The experiment was performed by two reagents, a gentleman and a lady, the instructor and assistant in psychology. The reagents will be designated by the letters B. and M. Both B. and M. have always enjoyed good health, except that B. has suffered somewhat from pen-paralysis in the right hand. Both are vigorous and active and are accustomed to indulge in gymnastic and outdoor exercise daily. B. had had considerable practice previous to this time in work upon an ergograph similar in construction to the one here used, and was not unpracticed at the outset. The other reagent had made a short series of observa-

tions the previous year and was therefore not unfamiliar with the work. The previous work will be included in this discussion.

The experiment continued over a period of more than three months, from January 27 to May 9. Periods of work of 5 to 20 days were alternated with periods of rest of 4 to 15 days. When two records were taken daily the first one came between 9:30 and 10:30 A.M. and the second at about 2 P.M. When one record a day was taken it came in the morning at the hour indicated. The time remained constant within reasonable limits.

For a record, the contractions of the finger were made every two seconds to the beat of a metronome until a movement was no longer possible. After a pause of a minute a new fatigue curve was written, which was followed, after a second pause of one minute, by a third. In the latter part of the experiment the number of exhaustions was increased to six, and the pause lengthened to two minutes. The records are given in the number of millimeters the weight was lifted during the three periods of work constituting a test.

No attempt was made to adhere closely in the daily habits to a regular plan of living. However, all unusually trying and fatiguing entertainments or diversions were interdicted as far as possible during the periods of work, so that we can regard the mode of life for the reagents, while the observations were being made, as reasonably normal and free from unusual strains or excitements.

TABLE I

In the following table, part I, are given all the records taken upon each reagent between January 27 and April 17. We have in the first column for each reagent the total height the weight was raised in mm. for either hand, in the second column the number of contractions, in the third the average height of the contractions, and in the fourth the average performance increase or decrease. The increase and decrease are indicated respectively by the plus and minus signs. Five periods of work separated by four pauses are shown. In the second part of the table are given the averages for the total height of lift, of the numbers of contractions and of the averages of the heights of contraction for each of the five periods of work.

TABLE I, PART 1

| DATE | B | | | | | | | M | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTAL HEIGHT | | NO. OF CON. | | AV. HT. OF CON. | | AV. PERFORMANCE INCREASE | TOTAL HEIGHT | | NO. OF CON. | | AV. HT. OF CON. | | AV. PERFORMANCE INCREASE |
| | R. H. | L. H. | R. H. | L. H. | R. H. | L. H. | | R. H. | L. H. | R. H. | L. H. | R. H | L. H. | |
| **1ST WORK PERIOD** | | | | | | | | | | | | | | |
| Jan. 27 | 1495 | 1107 | 62 | 50 | 24.1 | 22 | | 1239 | 1015 | 50 | 50 | 24.7 | 20.3 | |
| Jan. 27 | 1249 | 1086 | 57 | 52 | 22 | 20.9 | | 1089 | 525 | 47 | 41 | 23 | 11.9 | |
| Jan. 28 | 1120 | 1253 | 55 | 56 | 20.3 | 22.3 | | 924 | (413) | 47 | (17) | 19.6 | (29.3) | |
| Jan. 28 | 1100 | 1124 | 53 | 54 | 20.9 | 20.8 | | 991 | 728 | 46 | 41 | 20.9 | 17.7 | |
| Jan. 28 | 1176 | 956 | 59 | 53 | 19.9 | 18 | | 775 | 723 | 57 | 39 | 13.6 | 18.5 | |
| Jan. 29 | 1318 | 1100 | 58 | 54 | 22.7 | 20.3 | R. H. | 1078 | 772 | 56 | 49 | 19.2 | 15.7 | R. H. |
| Jan. 29 | 1178 | 943 | 57 | 49 | 20.6 | 19.2 | 1.1 | 1021 | 508 | 49 | 43 | 20.8 | 11.7 | —23 |
| Jan. 30 | 1347 | 956 | 65 | 45 | 20.7 | 21.2 | L. H. | 1074 | 764 | 50 | 48 | 21.4 | 16 | L. H. |
| Jan. 30 | 1163 | 917 | 64 | 52 | 18.1 | 17.5 | —16.3 | 937 | 768 | 46 | 49 | 23.9 | 15.6 | 15.4 |
| Jan. 31 | 1486 | 1094 | 62 | 49 | 24 | 22 | | 1048 | 967 | 56 | 47 | 18.7 | 20.5 | |
| Jan. 31 | 1154 | 1015 | 59 | 51 | 19.5 | 20 | | 684 | 916 | 41 | 46 | 16.7 | 19.9 | |
| Feb. 1 | 1104 | 914 | 60 | 44 | 18.4 | 20.8 | | 938 | 909 | 50 | 53 | 18.7 | 17.1 | |
| Feb. 1 | 1357 | 957 | 64 | 48 | 21.2 | 19.8 | | 896 | 754 | 47 | 47 | 19 | 16 | |
| Average | 1249 | 1033 | 59 | 50 | 21.1 | 20.6 | | 976 | 779 | 50 | 46 | 19.8 | 16.7 | |
| Rest of 9 Days | | | | | | | | | | | | | | |
| **2D WORK PERIOD** | | | | | | | | | | | | | | |
| Feb. 10 | 1675 | 1359 | 68 | 60 | 24.7 | 22.6 | | 1354 | 1325 | 58 | 68 | 23.3 | 19.4 | |
| Feb. 10 | 1775 | 1161 | 68 | 52 | 26.1 | 22.3 | | 1278 | 1164 | 57 | 48 | 22.4 | 24.2 | |
| Feb. 11 | 1498 | 1207 | 62 | 55 | 24.1 | 22 | | 1264 | 1316 | 53 | 53 | 23.8 | 24.8 | |
| Feb. 11 | 1578 | 1183 | 66 | 58 | 23.9 | 20.4 | R. H. | 1446 | 1084 | 53 | 49 | 27.2 | 22.1 | R. H. |
| Feb. 12 | 1474 | 1206 | 62 | 58 | 23.8 | 20.8 | —105.2 | 1402 | 1172 | 55 | 52 | 25.5 | 22.5 | 7.1 |
| Feb. 12 | 1074 | 1337 | 36 | 58 | 28.1 | 23 | L. H. | 1165 | 1008 | 51 | 43 | 22.8 | 23.4 | L. H. |
| Feb. 13 | 1159 | 1383 | 62 | 65 | 17 | 21.2 | 25.6 | 1435 | 1295 | 55 | 57 | 26 | 22.7 | —17.4 |
| Feb. 13 | 1049 | 1442 | 50 | 66 | 21 | 21.6 | | 1378 | 1143 | 59 | 52 | 23.3 | 22 | |
| Average | 1410 | 1284 | 59 | 59 | 23.8 | 21.8 | | 1340 | 1188 | 55 | 52 | 24.4 | 22.8 | |

| Rest of 4 Days | | | | | | | | 3D WORK PERIOD | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 18..... | 990 | 1364 | 54 | 68 | 18.3 | 14 | | 1733 | 1432 | 65 | 57 | 26.6 | 25.1 | |
| Feb. 19..... | 1150 | 1347 | 55 | 64 | 20.9 | 21 | | 1692 | 1182 | 65 | 55 | 26 | 21.5 | |
| Feb. 20..... | 1008 | 1237 | 58 | 69 | 17.3 | 17.9 | | 1388 | 1432 | 56 | 57 | 21.2 | 25.1 | |
| Feb. 21..... | 882 | 1263 | 53 | 64 | 16.2 | 19.7 | | 1370 | 1202 | 58 | 57 | 23.6 | 21.1 | |
| Feb. 22..... | 832 | 924 | 51 | 42 | 16.3 | 17.2 | R. H. | 1602 | 1448 | 62 | 60 | 25.8 | 24.1 | R. H. |
| Feb. 23..... | 1103 | 1136 | 68 | 65 | 16.2 | 17.4 | 18.5 | 1831 | 1398 | 70 | 57 | 26.8 | 24.5 | 12.6 |
| Feb. 24..... | 1200 | 1284 | 72 | 71 | 16.8 | 18 | L. H. | 1400 | 1474 | 59 | 61 | 23.7 | 24.1 | L. H. |
| Feb. 24 ..... | 959 | 1282 | 65 | 71 | 14.7 | 18 | —16.2 | 1414 | 1137 | 59 | 56 | 24 | 23 | 38.8 |
| Feb. 25..... | 869 | 1102 | 56 | 52 | 15.1 | 21.1 | | 1638 | 1390 | 64 | 56 | 25.6 | 25 | |
| Feb. 25..... | 692 | 1163 | 56 | 67 | 12 | 17.3 | | 1566 | 1769 | 63 | 67 | 24.9 | 26.4 | |
| Feb. 26..... | 780 | 1071 | 58 | 61 | 13.4 | 17.5 | | 1907 | 1415 | 73 | 46 | 26.1 | 30.7 | |
| Feb. 26..... | 942 | 1131 | 49 | 70 | 19.2 | 16.7 | | 1880 | 1878 | ..... | ..... | ..... | ..... | |
| Feb. 27..... | ..... | ..... | ..... | ..... | ..... | ..... | | 1442 | 1553 | 60 | 64 | 24 | 24.2 | |
| Feb. 27..... | ..... | ..... | ..... | ..... | ..... | ..... | | 1850 | 1701 | 69 | 61 | 26.8 | 27.8 | |
| Average ..... | 954 | 1192 | 58 | 64 | 16 | 19 | | 1626 | 1458 | 63 | 58 | 25.7 | 25.6 | |

TABLE I, PART 1—*Continued*

| DATE | B | | | | | | | M | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTAL HEIGHT | | NO. OF CON. | | AV. HT. OF CON. | | AV. PERFORMANCE INCREASE | TOTAL HEIGHT | | NO. OF CON. | | AV. HT. OF CON. | | AV. PERFORMANCE INCREASE |
| | R. H. | L. H. | R. H. | L. H. | R. H. | L. H. | | R. H. | L. H. | R. H. | L. H. | R. H | L. H. | |
| Rest of 6 Days | | | | | | | 4TH WORK PERIOD | | | | | | | |
| March 6 | ..... | 1785 | ..... | 88 | ..... | 20.2 | | 1585 | 1949 | 70 | 78 | 22.6 | 24.9 | |
| March 7 | ..... | 1671 | ..... | 80 | ..... | 20.8 | | 1820 | 1871 | 73 | 68 | 25 | 27.1 | |
| March 8 | ..... | 1636 | ..... | 76 | ..... | 21.6 | | 1870 | 1899 | 72 | 62 | 26.4 | 30.6 | |
| March 9 | ..... | 1763 | ..... | 82 | ..... | 21.5 | | 1567 | 1803 | 56 | 70 | 28 | 25.7 | |
| March 10 | ..... | 1967 | ..... | 94 | ..... | 20.9 | | 2119 | 2028 | 78 | 64 | 27.1 | 31.7 | |
| March 11 | ..... | 1897 | ..... | 87 | ..... | 21.8 | R. H. | 1869 | 2261 | 69 | 68 | 27.2 | 33.2 | |
| March 12 | ..... | 1755 | ..... | 83 | ..... | 21.1 | 43.3 | 1875 | 2070 | 68 | 62 | 27.5 | 34 | |
| March 13 | ..... | 1914 | ..... | 87 | ..... | 22 | L. H. | 1959 | 1967 | 62 | 70 | 31.6 | 28.1 | R. H. |
| March 14 | ..... | 2103 | ..... | 95 | ..... | 23.2 | 30.8 | 2099 | 2044 | 72 | 60 | 28.6 | 34 | 34.2 |
| March 15 | ..... | 2212 | ..... | 97 | ..... | 22.8 | | 2383 | 1993 | 84 | 67 | 28.4 | 29.9 | L. H. |
| March 16 | ..... | 2285 | ..... | 107 | ..... | 21.3 | | 2079 | 1908 | 76 | 62 | 27.3 | 30.7 | .87 |
| March 17 | ..... | 1923 | ..... | 91 | ..... | 21.1 | | 1950 | 1671 | 73 | 59 | 26.7 | 28.3 | |
| March 18 | 1703 | 1618 | 69 | 73 | 24.6 | 22.1 | | 1815 | 1675 | 73 | 52 | 25 | 32 | |
| March 18 | 1908 | 1783 | 75 | 88 | 26.2 | 26.3 | | 2079 | 1275 | 71 | 49 | 29.2 | 26 | |
| March 19 | 2019 | 2102 | 76 | 85 | 26.5 | 24.7 | | 1981 | 1970 | 78 | 60 | 25.4 | 32.8 | |
| March 19 | 1415 | 1694 | 61 | 78 | 23.2 | 21.7 | | 2168 | 1887 | 71 | 60 | 30.5 | 31.4 | |
| March 20 | 1633 | 1691 | 70 | 78 | 23.2 | 21.6 | | 2245 | 2019 | 76 | 67 | 30 | 30.1 | |
| March 20 | 2137 | 2032 | 79 | 91 | 26.9 | 22.3 | | 2288 | 1652 | 70 | 54 | 29.3 | 31 | |
| March 21 | 2103 | 2172 | 83 | 93 | 25.3 | 23.3 | | 2413 | 1955 | 92 | 58 | 26.2 | 33.7 | |
| March 21 | 1888 | 2158 | 78 | 95 | 24.2 | 22.7 | | 2129 | 2073 | 69 | 65 | 30.9 | 32 | |
| March 22 | 1651 | 2177 | 70 | 92 | 23.5 | 23.8 | | 2539 | 1886 | 83 | 56 | 30.6 | 34.6 | |
| March 23 | 1992 | 2362 | 88 | 103 | 22.6 | 23 | | 2367 | 2086 | 79 | 63 | 30 | 33.1 | |
| March 24 | 2273 | 2452 | 94 | 105 | 24.1 | 23.3 | | 2446 | 1870 | 80 | 58 | 30.5 | 32.2 | |
| March 24 | 2068 | 2526 | 88 | 120 | 23.5 | 21 | | 2479 | 1881 | 81 | 57 | 30.6 | 33 | |
| Rest of 1 Day | | | | | | | | | | | | | | |
| March 26 | 2180 | 2467 | 99 | 125 | 22 | 19.7 | | 2514 | 1957 | 83 | 58 | 30.3 | 33.7 | |
| March 26 | ..... | 2664 | ..... | 116 | ..... | 23 | | 2806 | 2242 | 95 | 66 | 29.5 | 34 | |
| Average | 1920 | 2019 | 86 | 93 | 26.4 | 21.7 | | 2132 | 1919 | 75 | 62 | 28.2 | 31.5 | |

| Rest of 18 Days | | | | | | | 5TH WORK PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April 14 | ..... | ..... | ..... | ..... | ..... | ..... | | 2625 | 1989 | 78 | 61 | 33.6 | 32.6 | R. H. |
| April 15 | ..... | ..... | ..... | ..... | ..... | ..... | | 2980 | 2157 | 90 | 64 | 33.1 | 33.7 | 11.7 |
| April 15 | ..... | ..... | ..... | ..... | ..... | ..... | | 2315 | 2230 | 77 | 63 | 30 | 35.4 | L. H. |
| April 16 | ..... | 2573 | ..... | 92 | ..... | 27.9 | L. H. | 2705 | 2171 | 87 | 72 | 31 | 30.1 | 129.5 |
| April 16 | ..... | 2245 | ..... | 84 | ..... | 26.7 | —171.5 | 2821 | 2628 | 94 | 77 | 30 | 34.1 | |
| April 17 | ..... | 2280 | ..... | 76 | ..... | 30 | | ..... | ..... | ..... | ..... | ..... | ..... | |
| Average | ..... | 2397 | ..... | 84 | ..... | 28.2 | | 2689 | 2235 | 85.2 | 67 | 31.5 | 33.2 | |

TABLE I, PART 2

| | B | | | | | | M | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R. H. | | | L. H. | | | R. H. | | | L. H. | | |
| | AMOUNT | NO. OF CON. | AV. HT. | AMOUNT | NO. OF CON. | AV. HT. | AMOUNT | NO. OF CON. | AV. HT. | AMOUNT | NO. OF CON. | AV. HT. |
| 1st period | 1249 | 59 | 21.1 | 1033 | 50 | 20.6 | 976 | 50 | 19.6 | 779 | 46 | 16.7 |
| 2d period | 1410 | 59 | 23.8 | 1284 | 59 | 21.8 | 1340 | 55 | 24.3 | 1188 | 52 | 22.8 |
| 3d period | 934 | 58 | 16.1 | 1220 | 63 | 19.3 | 1626 | 63 | 25.7 | 1452 | 58 | 25.6 |
| 4th period | 1920 | 86 | 26.4 | 2019 | 93 | 21.7 | 2132 | 75 | 28.2 | 1919 | 62 | 31.5 |
| 5th period | ..... | ..... | ..... | 2397 | 84 | 28.2 | 2689 | 85 | 31.5 | 2235 | 67 | 33.2 |

Table I contains all records taken from January 27 to April 17. During this time the method of experiment remained constant with the exception of the number of records daily. Part of the time two records a day were taken and part of the time only one.

The actual amount of practice gained is shown in a comparison of the averages of all records of the first and last periods for both B. and M.

| | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| First period | 1249 | 1033 | 976 | 749 |
| Last period | 1920 | 2397 | 2689 | 2235 |
| Difference | 671 | 1364 | 1713 | 1486 |

The right hand shows a greater gain for M. and the left for B. On account of injury to the right hand, B. suspended work from February 26 to March 18; previous to actual suspension the records had been invalidated by a broken mask. While the right hand had up to that time given generally as good or better records than the left, it never afterwards reached the height of the left except on one occasion.

The experiment began with the thought of working three times a day. On the first day two records were taken and three on the second. This proved a very severe regimen. The muscle soreness and the general physical condition which resulted were such as to convince us that such a task was too great to yield the best results, and accordingly two records a day were afterwards taken. The weight used was unusually heavy and that in a measure was the cause for such a result. Lack of inurement is the chief factor to be noted in these first records, and with so heavy a weight inurement comes slowly. In the first period the average performance increase in six days for the left hand of M. was 15.4 mm. and for the right hand of B. was 1.1; for the right hand of M. and the left hand of B. a loss of work was shown. The amount of exercise required to habituate one to an instru-

ment like this is great. The first performances induce a condition of extreme muscle soreness which shows itself chiefly in reducing the height of contractions and thus causing a falling off in the amount of work done.

*Analysis of Practice Effect on the Ergograph.*—There are four discoverable elements entering into practice gain upon the ergograph. The first is inurement, which has been discussed as a process of hardening and toughening of the skin where it comes in contact with the apparatus and of habituating the muscles to the strains which the unusual effort imposes. In spite of the best precautions the skin will be bruised and rubbed, and blisters will form where the pressure is greatest. These injuries affect the record after the first trial and continue to exert some influence until the bruises are healed and callouses formed. Muscular soreness and stiffness make their appearance shortly after the first trial and grow more severe for several days. Under such circumstances the reagent can not do his best. These conditions continued throughout the first work period, which is indicated by an average performance decrease for the left hand of B. and for the right hand of M. In the following rest period opportunity was given for recuperation. The condition, however, was somewhat aggravated when work was resumed, as is indicated by a decrease in several records. Generally speaking, inurement comes rapidly and becomes complete before any of the other effects of practice upon the ergograph and is on the other hand most fleeting, thus illustrating that fundamental law of biology which says that which is most recently and easily acquired is most likely to decay and disappear early. A suspension of practice for six days, as in the case of the third rest period, was sufficient to reduce some records through the loss in inurement that had already taken place. We shall see in the discussion later how this has affected the growth of practice.

The second element in the growth of practice is skill or perfection in the coordination of the movement. It is very difficult to test accurately the growth in this direction. The inexperienced reagent simply can not move his finger in the right manner to lift the weight with any degree of regularity. There is no lack

of strength. Every movement which is not purely hereditary and perfectly inborn requires some exercise before it can be performed easily, gracefully, regularly, and with the highest degree of efficiency. Our muscles do not under normal circumstances act separately. The middle finger is accustomed to contracting synchronously with the other fingers of the hand and so with all other muscles. Their movements are bound up in hereditarily coordinated groups which must be broken up, when any new movement is tried, and the activities associated with the activities of other muscles that act hereditarily in other groups. A muscle may be isolated and made to act more or less independently, but very few, if any, muscles do so naturally. This requires considerable practice. The movement employed on the ergograph is comparatively simple, and yet it is probably not accomplished, as Mosso alleged, by a single isolated muscle even when the greatest precautions are taken to prevent the contractions of other muscles. Much skill is required to make the contraction of the finger most efficient in raising the weight. The efficiency is the essential point. That means the application of the force to the point and in the way that it will lift the weight with the least waste of energy. This highest efficiency is not so easily attained. Neither reagent seemed to have attained it fully until the third series, when the greatest practice gains began to be made. Consciously it is felt as ease and smoothness of contraction, with a minimum of accessory movement. The perfectly coordinated movement is made without strain or undue manifestation of effort. When the experiment began every contraction was executed only with great demonstration of effort. All the fingers of the hand contracted simultaneously and the trunk and face joined sympathetically. The body was bowed well forward with each contraction and the opposite hand vigorously clenched. After a time these demonstrations grew less obvious, and at the beginning of an observation a number of contractions could be made with no apparent sympathetic movement. However, as the exhaustion point was approached, the effort grew more and more strenuous and the number of accessory movements increased until finally the whole organism was involved,

when no further contractions were possible. Toward the end of the experiment the left hand of M. and the right hand of B. would actually reach the exhaustion point without visible or mental signs of fatigue, and it seemed to avail nothing to put effort into it. This we take to be the highest perfection in the coordination of the movement. A movement once learned and practiced for a time is probably never forgotten. The inurement and habituation to it, together with the rhythmical performance and endurance in it are soon lost. The bicycle rider is quite as able, after giving up riding for several years, to make his wheel stand as he was when he quit practice, but he lacks the inurement and endurance to perform great feats. Again, the baseball pitcher does not easily forget the movements required to throw the various curves, although his arm may not hold out to pitch for a single inning. With the ergograph the perfection of the coordination is shown in the height of the contraction which is made and the regularity with which that height is attained at each contraction. The left hand of M. and the right hand of B. differed remarkably from the others in this respect. The contractions were of uniform height until the exhaustion point was closely approached, when it fell off rapidly, and effort seemed to avail little in keeping up the movement. The other hands, the right of M. and the left of B., showed a more gradual decline. The average number of contractions for both hands of either reagent appear in the second part of Table I.

The numbers of contractions for both hands of each reagent have increased steadily during the experimenting, the left hand of B. more rapidly than the right, surpassing the right during the third work period. The right hand of M. grew more rapidly than the left, increasing the difference which was shown at the beginning. In general it may be said that the height of contractions has increased steadily throughout the entire experiment, the exceptions being found in the right and left hands of B. in the third work period. This is to be accounted for by an injury to the right hand and an imperfect mask for the left.

The processes of eliminating the accessory and superfluous movements is one of the greatest psychological interest. The

feeling of effort is the psychological correlate of a bodily attitude. To make an effort is to place the body in the position in which all the muscles whose contractions can assist at all in the task are made to contract simultaneously and successively in the direction that will accomplish the work best. Efforts and feelings of effort are accompaniments of more or less widespread bodily activities. In this respect they relate themselves to the emotions with this distinction—that in effort it is the voluntary muscles that take the leading parts. The emphasis is laid upon them. When any effort is to be made, there is a tendency to revert to former types, to primitive modes of acting, such as are found in instinctive performances, where all the bodily movements are directed toward a single point, as upon an enemy in combat. All the muscles are innervated even when the contraction of one is desired, and too when the contraction of that one will better suffice alone. How, then, do the accessory movements that thus arise fall out and disappear, leaving only the desired muscular contraction? The method is that of trial and error which is the principle that seems to underlie all learning. An effort is made and a large group of muscles contract, the essential and the inessential. In the following effort there appears a tendency for the muscles in the group to vary in relation to one another with respect to the parts they take in the movement. Let us say that some inessential muscles do not join in the process. The contraction is successful. The absence of these is noted and in the next effort care is taken to see that they remain uncontracted. Their association with the essential muscles is thus broken up and their contractions become less likely to arise during succeeding efforts. In this way one after the other of the accessory contractions is eliminated until the movement is reduced to its lowest terms. But let us suppose that in the tendency of the group to vary some essential muscle fails to contract, in which case the contraction is not a success. This is noted by the reagent and it is seen to that the former group is contracted together. Thus the tendencies to vary are checked when essential elements are dropped and augmented when inessential elements fail to appear. If this tendency to vary is

checked before all the inessential elements have disappeared, the contraction will always be accompanied by accessory movements. Again, the tendency to vary may actually revive other movements that did not originally appear, but which are essential to the most successful accomplishment of the work. These will be preserved by the same process of selection. During the first days of practice the inessentials drop out very rapidly, but later many random variations are required before a new combination of muscles is found that will better accomplish the work, which accounts for the slow growth of practice.

Each new combination, whether brought about by the elimination of an inessential muscle or the bringing in of a new essential one, must be practiced long before the association is perfected. Accordingly there are periods in practice, which Bryan and Harter call the plateaus in the practice curve, when seemingly no gain is made. This is to be accounted for by the fact that during the time when the association is made among a new group by a random groping, this must be thoroughly ingrained, and while that is going on the process of random groping for further new combinations is checked. The new combination when discovered leads to a rapid gain in practice which is not improved upon until that is firmly fixed in the nervous structure. Further practice gain must wait upon still other combinations turning up fortuitously. The practice curve then shows sudden rises with long periods without change in elevation.

All these associations are more or less feebly established. When a contraction has been repeated a number of times the new pathway established in the nervous structure is broken up or rendered less permeable by fatigue, the nervous currents diffuse themselves over the older ones, the muscles that do the work are less strongly innervated, and this shortens the contraction, and accessory movements come in, increasing the rate of accumulation of waste products and checking repair in both muscles and nerve centers, bringing the effort suddenly to the exhaustion point.

The third element is that of rhythm. No great gain seems to have been possible until the movement could be done rhythmically. The contractions, as usual in experiments with the ergo-

graph, were made to the beating of the metronome. The time between the beats must be nicely divided between contraction and relaxation. There must be neither haste nor too much delay at any point. It is an easy matter, when time for consideration can be taken, to learn the movement that will be most effective in lifting the weight, but it is another thing to make it repeatedly in spite of feelings of increasing discomfort and weariness which tend most strongly to break up the coordination and the proper timing of the movement within the interval in which a full contraction must be completed. Each part of the movement must be the stimulus for making the next part, and so on, the completed movement becoming the stimulus of a new one. Each part must be separated by a time interval practically equal to the full reflex time for such an act. The movement then becomes a series of reflex actions joined together in serial order by habit. The various noises issuing from the apparatus during any contraction come to group themselves together in such a way as to have a cumulative effect in exciting the succeeding contraction. These successive stimuli are summated, apparently increasing enormously the number of contractions that can be made. When this stage in the perfection of the movement can be reached, it seems to go on of itself and ceases only when some extraneous influence intrudes itself to break the usual series of stimuli that lead up to the climax before contraction. Effort must be used either to repress the intruder or to execute the movement. Accessory movements begin to appear after that, and the reagent soon reaches the limit of his power. These accessory movements are energy-consuming and hasten the approach of exhaustion as has been shown. The rhythm of the movement once caught leads to the gradual increase in the number of contractions and is therefore an aid to endurance. Rhythm and skill can not easily be separated. Rhythm means skill in executing repeated movements.

The fourth element in the growth of practice is endurance. Without a doubt this is a distinct phenomenon. A reagent thoroughly habituated to the ergograph will make a long series of contractions with no apparent signs of fatigue or feelings of weariness. He will actually reach the exhaustion point without

any discomfort and perform the usual amount of work. Practice will enable such a reagent to make a larger number of contractions than he could otherwise make. Greater endurance means the power of the nerve center to excite a muscle to perform a certain work a greater number of times than it could before the exercise to which it has been subjected. Of the four elements into which practice gain has been analyzed, endurance is the one which is acquired most slowly; that is, it comes last. The left hand of B. especially and the right hand of M. develop the greater endurance. This is shown by the greater proportional number of contractions made by these fingers. The number of contractions has contributed more to the gain shown by these fingers than the increase in height of contraction. The left hand of M. began early to show great efficiency in coordination. The movement always seemed easy and was never attended by feelings of discomfort. The exhaustion point was reached without warning signal. The onset of paralysis was most sudden, as three or four contractions were usually all that could be made after the finger once failed to reach the usual height. The right hand of B. occupies an intermediate position. The early contractions in an observation were rhythmical and unattended by pain or discomfort. Long after the contractions began to fall off in height and the hand and arm experienced uncomfortable feelings, voluntary effort still availed somewhat to keep the finger contracting, although the height grew steadily less.

Our aim shall be to show how changes in these four different directions have contributed toward the total amount of practice gain shown by the reagents.

*Effect of rest periods upon practice gain and practice loss.*— The purpose of breaking the work up into a number of periods was to determine the practice loss that would result from the suspension of exercise for different periods of time. On one or two occasions the rest period was enforced. An examination of table I shows that during the first rest period an enormous increase of power had taken place. A comparison of the records for the four days previous to the rest with the first four immediately after it gives these results. These are averages of four records:

TABLE II

| AVERAGE OF THE FOUR RECORDS JUST | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| Before the rest period | 1276.2 | 995 | 891 | 886.5 |
| After the rest period | 1631.5 | 1209.5 | 1335.2 | 1222.2 |
| The difference | 355.3 | 214 | 444.2 | 335.7 |

AVERAGES OF ALL RECORDS FOR FIRST AND SECOND PERIODS

| | R. H. | L. H. | R. H. | L. H. |
|---|---|---|---|---|
| First period | 1249 | 1033 | 976 | 779 |
| Second period | 1410 | 1284 | 1340 | 1188 |
| The difference | 161 | 251 | 364 | 409 |

The table shows that M. has added between one-third and one-half of the average of four records before the rest to the average of the first four records after the rest. The proportion is not so great for B., yet it is high. The averages for all records before the rest compared with the averages for all records during the second period are found in the second part of the table. They show considerable practice gain. The left hand for M. shows a greater actual gain here than in the first part of the table, the figures being 409 for the difference in the average of all records, and 335.7 the difference in the average of the four compared, the later records being lower than the earlier ones. Both reagents suffered greatly from lack of inurement during the first period. (The protocol contains a note to the effect that the general bodily condition was exceedingly unfavorable to the continuation of the experiment.) The right hand of M. and the left hand of B. lost continuously, showing that the condition grew worse rather than better, six days not being sufficient to habituate the hands to the experiment. During the rest complete relief apparently was found for the general bodily condition so that the first records after the rest show considerable increase. The average daily increase, however, for the second period is either very small or a negative quantity except for the left hand of B. Perfect habituation, therefore, had not been attained. Two records a

day were thought to be a pretty severe task, and a rest period of four days was again taken, constituting the second rest period. When work was resumed the records of M., as the table shows, presented an increase equivalent to nearly one-fourth. On the last day before the work was suspended the mask for the right hand of B. was broken, and it was some days before a new one could be made to fit well. The one that was used was extremely painful, and the reagent was unable to reach anything near the maximum attained during the second period of work. Even the left hand during the same period showed no practice gain whatever.

As two records had been thought to be a pretty severe task, the reagents feeling more or less exhausted by evening, only a record a day with either hand was taken during the first five days of the third period. The records of M. during the third period, which continued for ten days, show with some fluctuations a steady practice gain, 12.6 mm. average performance increase for the right hand and 38.8 mm. for the left. The records of the left hand actually exceeded the records of the right upon two occasions.

Since the records after the first two rest periods[1] showed a considerable increase over those taken just before the rest, proving that no loss of practice effect had taken place, the work was again suspended for six days, with a view of testing further the question of practice loss. The average daily performances during the third series are almost double the same averages for the first period.

The average for the four records for M.'s right hand just previous to the third rest was 1770 mm. and for the four just after, 1785.5 mm., and of the left hand for the four before the third rest 1636.7 mm. and for the four after, 1880.5 mm. During the rest the right hand had thus gained slightly and steadily in power, and the left very considerably. So far as the apparent bodily condition was concerned, inurement and habituation had become complete, for no uncomfortable effects of any kind seemed to remain after observations during the third period of

[1]Amberg: *Ueber den Einfluss von Arbeitspausen auf die geistige Leistungsfaehigkeit.* Psychologische Arbeiten (Kraepelin), 1896, Band 1, s. 30.

work. We can not therefore attribute the gain here to the relief, during the rest, from the generally unfavorable bodily conditions which had arisen through the severity of the work before the third rest. The hypothesis which seems most applicable is that, as a result of exercise, the nerve centers and muscles were in a state of incipient exhaustion, and that during the rest period they built themselves up to the highest level of metabolic change for which they have been prepared by the exercise. This is a manifestation, apparently, of the advantages of not over-training, that is, the maximum performance of a muscle is to be attained only after a suspension of practice for a few days. This point will come up again.

During the fourth period the work continued for nineteen days. On the first eleven days only one record a day was taken and on the remaining days two records a day. The left hand of M. started out considerably better than the right and remained ahead for eight days. The left then lost for a considerable time while the right made steady and rapid gains during the whole period. The left, however, began again to show great practice gains when two records a day were taken up, and continued to gain steadily and rapidly until the experiment was given up.

*Influence of practice by one hand upon that of the other.*— B. injured the right hand so that it was impossible to wear the mask, and no records of any kind were taken for twenty-two days. While the left hand had shown a loss during the third series and none of the records were equal to the best in the second series, the practice gain as shown by the records at the beginning of the fourth series was surprisingly great, and from that time on to the end of the experiment the practice increase was uniform and considerable. The right hand began practice again, and from the records it would appear that it had gained almost equally with the left hand during the interval in which the left only was exercised. In order to see how much gain has actually taken place we must compare the average for the four records of the first part of the second series with the first four records taken after practice was resumed in the fourth. Before the influence of a lack of inurement showed itself the average for the normal records of the second period was 1602.4 and for

the first five records, after the work was resumed in the fourth period the average was 1735.6. The averages for the records taken at the same time with the left hand are, second period, 1243.2 mm.; fourth period, 1777.6 mm. The gain for the right hand is 133.2 mm. and for the left hand 534.4 mm. It is evident then that while the right hand shows considerable practice gain, it does not approach the gain made by the left hand during the same period. The right hand, however, was lower than the left, and during the remainder of the experiment it did not succeed more than twice in equaling the performances of the left. The averages for all records during the fourth period for the two hands are, right, 1920 mm.; left, 2019 mm.

It is a question here of the effect of vicarious practice. During the long interval in which the right hand of B. did not work, it made a clear gain of 133.2 mm. It had, however, lost in habituation; several records, one on May 19 and one on May 20, are manifestly below the normal, and the protocol shows that the hand suffered more or less muscle soreness after work was resumed. It is clearly evident that, in so far as lack of inurement is due to local conditions in the muscle, there can be no vicarious practice effect. The growth in the perfection of coordination and rhythmical execution in one hand may possibly be affected by practice of the other. If endurance is dependent upon changes in the conditions of the cortical centers of the brain, it, too, may be affected by vicarious practice. But it would seem probable that a movement which is perfectly coordinated and rhythmical-controlled would depend quite largely for its control upon the lower nervous centers, and that those on the one side act more or less independently of those on the other side. If, then, there be such a thing as vicarious effect, it must take the direction largely of coordination and rhythm.

Certain experiments were made to test the question of vicarious practice. They were made in May and June, 1901. The right hand of B. and the left hand of M. wrote five records apiece, then the left hand of B. and the right hand of M. were made to write two or three records a day for nine days, after which the right hand of B. and the left hand of M. again wrote five records apiece. These records are contained in the following

table. A different method of recording results was used at that time, so that while these figures are considerably higher proportionately than the figures in the previous tables, they are not directly comparable with the figures in the first table:

TABLE III

| DATE | B. | | M. | |
|---|---|---|---|---|
| | R. | L. | R. | L. |
| May 24 | 1910 | | | 1874 |
| May 24 | 1997 | | | 1901 |
| May 24 | 2156 | | | 1347 |
| May 25 | 1938 | | | 2275 |
| May 25 | 1663 | | | 1601 |
| Averages | 1934 | | | 1799 |
| May 26 | | 1703 | 1769 | |
| May 27 | | 1721 | 2110 | |
| May 27 | | 2165 | 1683 | |
| May 27 | | 1674 | 1996 | |
| Av. of four records | | 1784 | 1864.3 | |
| May 28 | | 1810 | 1909 | |
| May 28 | | 1969 | 1950 | |
| May 28 | | 1954 | 2015 | |
| May 29 | | 1407 | 2164 | |
| May 29 | | 1534 | 2139 | |
| May 29 | | 1452 | 1835 | |
| May 30 | | 1364 | 1931 | |
| May 30 | | 1773 | 1940 | |
| May 31 | | 1214 | 1413 | |
| May 31 | | 1609 | 2086 | |
| May 31 | | 1051 | 1928 | |
| June 1 | | 1521 | 2016 | |
| June 1 | | 1908 | 2266 | |
| June 2 | | 1887 | 1888 | |
| June 3 | | 1351 | 2419 | |
| June 3 | | 1588 | 2445 | |
| Av. of four records | | 1663 | 2207 | |
| June 4 | 1831 | | | 2205 |
| June 4 | 2443 | | | 1901 |
| June 4 | 1786 | | | 1967 |
| June 5 | 1776 | | | 2073 |
| June 5 | 1812 | | | 2190 |
| Averages | 1929.6 | | | 2067 |

The averages for the right hand of B. show no practice gain; figures are 1934 in first period and 1929.6 in second period. The left, however, has lost during the period of work quite considerably, as shown by the average for the first four records, 1784, when compared with the average for the last four, 1663. The knuckle was inflamed through the imperfect fit of the mask, which made it impossible to continue the experiment further. This inflammation of the knuckle is due to lack of inurement, for later the knuckle recovered completely. This, too, may account for the fact that no gain in practice was made by the left hand. The left hand of M., however, shows a considerable practice gain in its second period of work over the first, the figures being 1799 and 2067, and the right hand, with some fluctuations, gains steadily in practice effect as shown by the averages for first four records, 1864.3, compared with average of the last four 2207. The results are therefore inconclusive. Neither reagent was sufficiently practiced to insure that degree of habituation which seems to be necessary to get uniform results. The difficulty lies in the fact that if the practice by one hand be suspended long enough to establish a clear gain by the other, the first will lose so much in habituation that the records afterwards will be affected by this loss. A sufficient number of records from which to get a good average can not be taken without inducing a condition of muscle soreness that is prejudicial to the best results. The total results, then, of all our observations upon vicarious practice would favor the hypothesis that there may be vicarious practice effect which is chiefly in the direction of coordination and rhythm.

*Relative standing of right and left hands.*—At the beginning of the experiment the right hands of both reagents, it is to be seen, showed considerable superiority over the left hands. Before the end of the first period of work, the left hand of M. showed a slight advantage over the right. In the second period the right again proved itself superior and maintained the superiority until near the end of the third period, when the left surpassed it and maintained its position for several records after the beginning of the fourth period of work. However, before the experiment was finally completed, the left hand was able to write as great a

record as had been obtained from the right. As both hands had reached the limit that could be recorded on the apparatus, it is difficult to tell what would have been the relative standing had the experiment been continued further.

With B. the right hand maintained its supremacy until the suspension of exercise with it was caused by a broken mask and injury to the hand. After exercise was taken up in the fourth series it never again quite succeeded in equaling the left hand.

Further comparisons of right and left hands for both reagents must be made on the basis of height of contraction. M. found the movement of the left hand always easier than that of the right. During the first three periods of work, however, the right hand made a higher average contraction than the left. During the fourth period the left hand gained considerably in the height of contraction, surpassing the right, but lost in the number of contractions. If our interpretation that the height of contraction represents perfection of coordination in movement be correct, then the left hand grew continuously in this respect. But as a highly coordinated movement is more fatiguing than a less highly coordinated one, we might expect that there would be some loss in endurance, which is shown by a reduction in the number of contractions. In case of B. the right hand was superior to the left in all respects except in number of contractions and maintained its superiority until work had to be given up. The left hand, however, grew very slowly in height of contraction, even to the end of the fourth period of work. The enormous practice gain which it made was due almost entirely to increase in power of endurance and rhythm of movement. The increase in number of contractions began during the third period of work and the number continued to grow up to the end of the fourth period. Here we have again a certain compensation. The hand lacked perfection of coordination, but it more than made up in endurance. The movement was always attended with more or less difficulty and never seemed to be easily or gracefully performed. This is further evidence that a highly coordinated movement is expensive of energy, although it may be proportionately more effective in the accomplishment of work.

The right hand was superior to the left in the coordination of the movement, but it lacked in endurance. It approached the exhaustion point closely before any manifest feeling of discomfort arose, when its power waned rapidly. The left hand lost gradually and more or less uniformly from the beginning to the point of exhaustion, and its movements were always accompanied by more or less uncomfortable sensations. Voluntary effort persistently applied seemed to enable it to keep up the contraction. The reverse was true in even a more striking manner for the left hand of reagent M. It made a few long contractions of almost uniform height and reached the exhaustion point without warning. Demonstrations of effort seemed inhibitory rather than beneficial. The right hand showed about the same general character of record as the right hand of B.

Statements with regard to the relative capacity of the two hands would be difficult. Had the experiments closed at any one of several different times, we might have been able to state that the left showed greater capacity for practice than the right, or by stopping at different times, that the capacity for practice of the two was relatively the same. Different muscles in the same person seem to show idiosyncracies in the way they work. What one accomplishes in the way of skill another makes up through endurance.

*The Validity of Ergograph Records.*—In view of the results set forth above the question arises whether the ergograph can really be used as a test of the work capacity or fatigue condition of an individual. The most pertinent fact to be observed in the results is that they show with some fluctuations a steady and enormous increase as a result of practice, and that so far as this experiment goes, and this is the conclusion of other experimenters, practice gain is practically unlimited. There is, however, a limit to practice gain. Practically it has been reached in the training of trotting horses and of professional sprinters and oarsmen, but the conditions in all such events can not be controlled. Wind, weather, track, and water are important factors that can not be kept uniform. While fluctuations in the records are most manifest, in the long run they are far outweighed by the increase which results from practice.

The following table will show the average performance increases for every period of work and for both hands of each reagent.

| | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| First period | 1.1 | —16.3 | —23 | 15.4 |
| Second period | —105.2 | 25.6 | 7.1 | —17.4 |
| Third period | 18.5 | —16.2 | 12.6 | 38.8 |
| Fourth period | 43.3 | 30.8 | 34.2 | .87 |
| Fifth period | ..... | ..... | 11.7 | 129.2 |

This table shows that, generally speaking, the rate of practice gain has increased throughout the whole experiment. The lower average performance increases in the earlier part of the experiment, which in some cases are negative quantities, were due, first, to the lack of inurement which actually reduced the height of the records for some days, and, second, to the imperfection of coordination and rhythm of the movement. The completion of the process of inurement is shown by the absence of any further muscle soreness, and the growing perfection of the coordination and rhythm was shown by the gradual disappearance of accessory and sympathetic movements. When this condition had been brought about in both reagents, the practice gain was great and more steady. It is apparent, then, that the ergograph records will have slight validity until after inurement has become thorough and the coordination of the movement is complete. Although great fluctuations in the records are to be expected, greater even than before this condition has arisen, yet they tend uniformly toward an increase. The study, then, of influences which are supposed to affect the ergograph records must be made in view of the practice gain. These influences must be seen by the way they affect the rate of practice gain. First, the reagents must be thoroughly inured to the experiment and brought up to the highest perfection in the coordination of the movement; secondly, they must then continue their records until the average increase from record to record is reasonably established, and

where it is necessary to suspend exercise for any length of time caution must be taken against making the time too long lest the records taken afterwards be affected by the loss of inurement, which comes rapidly and is most potent in influencing the height of the records after the first two or three have been taken. A few records taken upon unpracticed subjects, for instance, both before or after some influence which is thought to affect muscular power, are therefore without the slightest claims whatever to trustworthiness. The ergograph is quite unadapted to obtaining statistics upon a large number of individuals, except they be of the most general character. It may be used for obtaining accurate results only upon individuals studied under the most exacting conditions and for long periods of time. The work is exhausting and therefore tends to create an unfavorable disposition towards the experiment itself. This, however, will depend very much upon the number of records a day. Our experiment seems to indicate that not more than two records a day for each hand should be taken. When two records a day were taken the greatest practice gains were made, although in the earlier part of the experiment, before the reagent had become thoroughly habituated and skilled, that seemed a pretty heavy task.

*The conditions under which practice gain is greatest.*—The influence which the rest periods have exercised upon the growth of practice has already been touched upon, but a more detailed study of the effects from a suspension of practice for a period yields certain interesting results. In the following table we have brought together the average daily performances for the last four days before each rest period and for the first four days after each rest period. The number four is more or less arbitrarily chosen. The effects of incomplete inurement are usually shown within two days, and after that they begin to disappear.

TABLE IV

| | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| Before rest | 1312.2 | 999.5 | 891.5 | 886.5 |
| Rest 9 days. | | | 9 days. | |
| After rest | 1631.5 | 1227.5 | 1355.5 | 1222.2 |
| Difference | 369 | 228.0 | 464.0 | 335.7 |
| Before rest | ..... | 1342 | 1355.5 | 1154.5 |
| Rest 4 days. | | | 4 days. | |
| After rest | ..... | 1302.8 | 1545.7 | 1312 |
| Difference | ..... | —39.2 | 190.2 | 157.5 |
| Before rest | ..... | 1116.7 | 1769.7 | 1637 |
| Rest 6 days. | | | 6 days. | |
| After rest | ..... | 1713.7 | 1710.5 | 1880.5 |
| Difference | ..... | 597.0 | —59.2 | 243.5 |
| Before rest | 2128.7 | 2552.3 | 2561.2 | 1987.5 |
| Rest 20 days | | | 18 days. | |
| After rest | 2427.6 | 2366 | 2656.2 | 2139 |
| Difference | 298.9 | —186.3 | 95 | 151.5 |
| Before rest | 2427.6 | 2305.5 | (average of 3 | |
| Rest 5 days. | | | records.) | |
| After rest | 2549.4 | 2678.4 | | |
| Difference | 121.8 | 372.9 | | |

The table shows that there were six periods of work with five periods of rest. Except on three occasions there has been no loss of power shown after a rest. These occasions are, the left hand of B. after the second rest and after the fourth rest, and the right hand of M. after the third rest. In the case of B. some unfavorable disposition seemed to have affected all the records deleteriously, as the second work period and the loss of the left hand after the fourth rest period which lasted twenty days may be attributed to a loss in inurement. The rest period here was twenty days. In the case of M.'s right hand there are two accidentally low records among the four that were averaged. Had we taken the average of five the result would have been

entirely different, for the right hand showed uniform and rapid gain afterwards. We may be warranted, therefore, in saying that practice effect on the ergograph is not easily lost since some gain is shown after a rest period of twenty days. The gain which is shown after the first two rest periods is undoubtedly due to the fact that inurement was not complete before the rest. After the other rest periods, the gain must find explanation upon some other ground. While it is not equal to the amount of gain which would have been made during the pause, had the exercise been kept up, it is nevertheless a real and permanent gain. Some light will be shed upon this point by a comparison of the amounts of work that were done at morning observations with the amounts of work that were done at the afternoon observations.

In the following table we have the averages of morning observations compared with the averages for afternoon observations. The table makes this comparison between all the records for the first half of the experiment and all those for the last half:

TABLE V

FIRST HALF OF EXPERIMENT

| | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| Average of A.M. records | 1377 | 1157 | 1174 | 1070 |
| Average of P.M. records | 1286 | 1007 | 978 | 817 |
| Difference | —91 | —150 | —196 | —223 |

SECOND HALF OF EXPERIMENT

| | B. | | M. | |
|---|---|---|---|---|
| | R. H. | L. H. | R. H. | L. H. |
| Average of A.M. records | 1893 | 1742 | 2115 | 1800 |
| Average of P.M. records | 1901 | 1784 | 2150 | 1863 |
| Difference | +8 | +42 | +35 | +63 |

These figures show that in the first half of the experiment the morning records have averaged uniformly higher than the afternoon records, and that in the second half of the experiment the afternoon records have averaged uniformly higher than the morning records.

We find in this a further confirmation of the suggestion made above that until inurement is perfect exercise induces a condition within the muscles themselves which reduces their capacity for work. In the first observations the morning record produces a condition of local fatigue which influences deleteriously the afternoon record. By the following morning this condition is relieved, or if not completely so, the reagents are better able to work than they are in the afternoon. After inurement has become perfect, as it seems to have been in the latter part of the experiment, the morning practice actually influences favorably the afternoon practice. The morning record does this perhaps by creating a favorable disposition toward the experiment, a disposition to excel or rival oneself; and, again, a certain amount of preliminary exercise, which is in the nature of a warming-up process, produces a condition of motor excitement which is favorable to the attainment of the maximum. It should be observed, further, as practice goes on recovery is more speedy, so that while the effects of the morning exercise in the earlier part of the experiment are still manifest in the afternoon, in the latter part of the experiment the recovery is not only complete, but the organism has actually built itself up as a result of the practice in the morning, and yet it is not quite clear how a thoroughly inured reagent could benefit from morning practice by afternoon. The process of building up of cells has been thought to go on more slowly and to require the longer periods of sleep to accomplish itself.

We have in this, then, a further demonstration of the fact that the lack of inurement is in part responsible for the great gain that has been made during the first two rest periods, and that it is not the lack of inurement which is accountable for the gains made during the last rest period. No muscle soreness of importance manifested itself, and the fact that afternoon records have

fallen out uniformly higher than morning records is pretty good proof that there is none. We must therefore attribute the increase to the general processes of upbuilding which take place as the result of practice, and that we have here a demonstration of the reasonableness of the phenomenon of overtraining which has been so often observed empirically. Prize fighters allow two or three days for "drying out" before a fight, during which training is suspended. The amount of practice which will yield the greatest increase in power keeps the organism in a condition of incipient exhaustion, so that the maximum performance for which the training may have prepared the organism is most likely to be attained only after a suspension of practice for a day or two, to allow the organism to build itself up. Fatigue is, therefore, a necessary condition of practice gain; it is essential to growth in general.

*Recuperation.*—An observation, as has been stated above, consisted of three fatigue curves, the first and second, and the second and third being separated by minute pauses. The question of the value of the pause immediately presents itself, and, furthermore, that of the influence of practice upon the relative efficiency of the pause at the beginning and end of the experiment.

In the following table the average amounts of work for the successive curves for all periods of work have been brought together, along with the total amounts of work for the three curves. Percentages for the second and third curves are given, the first curve being taken in every case as 100 per cent.

TABLE VI

B.

| WORK PERIOD | R. H. | | | | | | | L. H. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % |
| First .... | 1249 | 875 | 100 | 220 | 25.1 | 154 | 17.6 | 1033 | 792 | 100 | 146 | 18.4 | 94 | 11.8 |
| Second .. | 1410 | 914 | 100 | 290 | 31.6 | 216 | 23.8 | 1284 | 878 | 100 | 241 | 28.5 | 166 | 17.9 |
| Third.... | 934 | 715 | 100 | 132 | 18.4 | 87 | 12.1 | 1220 | 820 | 100 | 248 | 30.2 | 152 | 18.5 |
| Fourth .. | 1920 | 1309 | 100 | 357 | 27.2 | 253 | 19.3 | 2019 | 1188 | 100 | 443 | 37.2 | 387 | 32.5 |
| Fifth .... | 2428 | 1405 | 100 | 517 | 36.8 | 505 | 35.9 | 2414 | 1308 | 100 | 601 | 45.8 | 505 | 38.6 |
| Sixth.... | 2549 | 1442 | 100 | 581 | 42.2 | 544 | 37.7 | 2680 | 1488 | 100 | 622 | 41.8 | 569 | 38.8 |
| Gain %... | .... | .... | ... | .... | 17.1 | .... | 20.1 | .... | .... | .... | .... | 23.4 | .... | 27.0 |

M.

| WORK PERIOD | R. H. | | | | | | | L. H. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % |
| First .... | 976 | 849 | 100 | 135 | 15.9 | 81 | 9.5 | 779 | 587 | 100 | 102 | 17.3 | 83 | 14.1 |
| Second .. | 1340 | 1035 | 100 | 187 | 18 | 118 | 11.4 | 1188 | 944 | 100 | 173 | 18.3 | 83 | 8.7 |
| Third ... | 1626 | 1230 | 100 | 227 | 18.3 | 168 | 13.6 | 1458 | 1108 | 100 | 198 | 17.8 | 147 | 13.2 |
| Fourth .. | 2132 | 1392 | 100 | 397 | 28.5 | 341 | 24.4 | 1919 | 1267 | 100 | 361 | 28.4 | 293 | 23.3 |
| Fifth .... | 2689 | 1602 | 100 | 546 | 34 | 541 | 33.7 | 2235 | 1399 | 100 | 413 | 29.5 | 424 | 30.2 |
| Gain %... | .... | .... | .... | .... | 18.1 | .... | 24.2 | .... | .... | .... | .... | 12.2 | .... | 16.1 |

This table shows, with one or two variations, a constant and proportionately increasing value for the one-minute pause. The first pause has greater efficiency than the second. For B. the right hand shows an increase of 17.1 per cent in the first pause, and 20.1 per cent in the second. The left shows an increase of 23.4 per cent in the first pause, and 27 per cent in the second. For M. the right shows an increase of 18.1 per cent in the first pause and 24.2 per cent in the second. The left hand shows an increase of 12.2 per cent in the first pause, and 16.1 per cent in the second. It appears, then, that the left hand has probably made a little larger gain in recuperative power than the right, and that the recuperation during the second pause has been proportionately greater than in the first, that is, the value of the second pause has grown proportionately more rapidly than the first.

This strikes us as a very significant and important point. At the end of the first curve the reagent has reached a point of complete exhaustion for voluntary effort. In one minute he makes a certain amount of recovery. He works again to the point of exhaustion and makes a certain recovery which is less than in the first pause. Practice renders the first pause increasingly more valuable and at the same time enhances the value of the second to even a greater extent. The emphasis is to be laid upon this: Exhaustion does not always mean the same thing. It may be understood why recovery from exhaustion should grow with practice, but it is not quite so clear why recovery from the second exhaustion should grow through practice more rapidly than from the first. Let one suggestion suffice: The amount of work done in writing the first curve is greater than in writing the second. The rate of recovery may depend upon the amount of work done just previous to the recuperation period. The paralysis resulting from the first work is due mostly, let us suggest, to the presence of accumulated waste products in the nervous centers. A certain proportion will be removed in the following pause. During the writing of the second curve, which requires less time, the accumulation of waste will be less. Since the paralysis is now due to the exhausted condition of the cells as well as the presence of waste products, the recovery from the removal of toxic waste will be more complete or go on more rapidly, and thus create a more favorable disposition for work. The favorable disposition is further enhanced by the motory excitement which follows the effort in writing the first curve, and it may be increased during the writing of the second. The more rapid recuperation during the second pause may be attributed to the higher degree of motory excitement at that time. The exception to the constantly increasing value of the pause is to be found in the third period for B.'s right hand. In the third period the right hand of B. was rendered practically useless by the fact of the broken mask which has been spoken of before. The work was suspended because it proved too painful to be continued. The condition so far as its effects upon the reagent were concerned was like a return to a condition before which any

practice had been taken, so that the pauses would have about the same value that they would have for an unpracticed reagent. A similar set of circumstances seemed to affect the work of M.'s left hand in the second period, making the second pause less valuable for recuperation.

The recuperative value of these pauses was studied in another way. When an observation was begun, the contractions of the finger were continued until complete exhaustion was reached, that is, until no further contractions were possible. The last contractions in any fatigue curve were therefore very short and made with great manifestations of effort, all the muscles of the body joining sympathetically in the movement, and their activity increased in violence and extent as the exhaustion point was approached. It was thought that the amount of work the contracting finger was accomplishing was very small in proportion to the actual expenditure of energy, that is, there was a great waste of energy here, and that if work were suspended as soon as it became clear, through the amount of effort that was necessary to make a contraction, that the exhaustion point was near, the waste of energy would be stopped. Upon the approach of exhaustion the reagent gradually falls into the condition of an uninured reagent. The work produces in the arm temporarily the feelings of muscle soreness and stiffness which ordinarily arise in the members of an unpracticed reagent. By the avoidance, then, of this condition, it was thought that greater work capacity would be shown. Therefore, observations in which the reagent ceased to contract the finger as soon as the symptoms of fatigue became strongly apparent, were alternated with others in which each fatigue curve was carried quite to the exhaustion point.

In the following table, the averages of the curves which were carried to the exhaustion point are compared with those that were stopped short of the exhaustion point. They are designated "to exhaustion," and "not to exhaustion."

TABLE VII

B.

| | R. H. | | | | | | | L. H. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % |
| Not-exhaustion | 2569 | 1444 | 100 | 581 | 42.2 | 544 | 37.7 | 2680 | 1488 | 100 | 622 | 41.8 | 569 | 38.8 |
| Exhaustion.... | 2428 | 1405 | 100 | 517 | 36.8 | 505 | 35.9 | 2423 | 1387 | 100 | 557 | 40.1 | 479 | 34.5 |
| Differences | 141 | 39 | ... | 64 | 5.4 | 39 | 1.8 | 257 | 101 | ... | 65 | 1.7 | 90 | 4.3 |

M.

| | R. H. | | | | | | | L. H. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % |
| Not-exhaustion | 2885 | 1675 | 100 | 622 | 37.1 | 584 | 34.8 | 2563 | 1430 | 100 | 550 | 38.4 | 559 | 40.6 |
| Exhaustion.... | 2689 | 1602 | 100 | 545 | 34 | 540 | 33.7 | 2235 | 1399 | 100 | 413 | 29.5 | 424 | 30.2 |
| Differences | 196 | 73 | ... | 77 | 3.1 | 44 | 1.1 | 328 | 31 | ... | 137 | 8.9 | 135 | 10.4 |
| (New weight) | | | | | | | | | | | | | | |
| Not-exhaustion | 1224 | 646 | 100 | 313 | 47.1 | 264 | 40.9 | 1198 | 590 | 100 | 327 | 50.4 | 281 | 47.6 |
| Exhaustion.... | 1132 | 666 | 100 | 268 | 40.2 | 194 | 29.2 | 1110 | 670 | 100 | 240 | 35.8 | 196 | 29.3 |
| Differences | 92 | —20 | ... | 45 | 6.9 | 70 | 11.7 | 88 | 120 | ... | 87 | 14.6 | 85 | 18.3 |

These tables undoubtedly show, by the greater percentages which the fatigue curves after the pause offer, that the pause is more efficient when the reagent does not work to the exhaustion point; the differences except in one case favor the "not to exhaustion" curves.

The question arises whether this is due to the greater recuperative value of the pause or to the fact that the nervous centers have not completely exhausted all their energies and the residue remaining back in the centers is carried over and added to the amount which is restored during the pause. In favor of the first hypothesis is the fact that when the contractions are continued to the exhaustion point they produce a condition of temporary or incipient muscle soreness from which recovery during the pause is not complete, in part because recovery is more slow, and hence this condition of the muscles is inhibitory. Introspec-

tion would incline us to this point of view. Furthermore, the amount of increase after the pauses in the "not exhaustion" curves seems to be greater than the amount of loss, which is sustained by the fact that the curve is not carried to the exhaustion point. Our figures are scarcely sufficient to give an unequivocal answer. Undoubtedly these accessory movements are energy-consuming and may, therefore, by exhausting a greater number of nerve centers and creating a larger accumulation of waste products, actually prevent the most rapid and full recovery of those centers whose activities we are trying to study. The question can be answered finally only by further investigations.

The general growth of practice during these "exhaustion" and "not exhaustion" observations was evident and surprisingly great. The limitations of the apparatus were reached by both hands of both reagents, and it was thus impossible to trace it completely. It seemed at the beginning of the experiment that with the weight which we used the limits of practice effects must certainly be reached before those of the apparatus had been exceeded. The weight was for M. increased by almost a kilogram. The observations with this weight, which is now about 4.5 kilos, are included in a later table. The results seem to confirm those for the smaller weights. The percentages of increase for "exhaustion" and "not exhaustion" are greater than for the other weights. The first fatigue curve is therefore shorter than when the smaller weight is used, but the larger percentages representing the second and third curves seem to indicate that the recuperation after a one-minute pause was greater proportionately than when the smaller weight was used. This presents the interesting point of the way a heavier weight affects respectively the endurance and skill acquired in using a lighter weight. With the smaller weight a greater number of contractions was necessary to exhaust the finger, that is, greater endurance was required. Endurance is dependent upon the number of successive explosions of which the nerve centers are capable before they cease to respond, and hence recuperation after endurance will mean, in a measure, cell reconstruction. In the longer period of work the removal of waste can more nearly keep pace with the

production of the same. The less number of contractions which is possible in lifting a heavier weight will therefore mean a less degree of cell exhaustion and a more rapid generation of waste products. The lifting of the heavier weight requires a greater force of contraction in the muscle, and this is dependent upon more vigorous innervation from the nerve-centers. The paralysis of the muscles when exhaustion comes will result from the accumulation of the waste products in the nerve center. The recovery that comes from the removal of waste products during the pause will be more rapid than through the reconstruction of the cells which must be necessary after an exercise in endurance. Although the figures showing the heights of contraction have not been preserved, about the same degree of perfection of skill was shown in lifting the larger weight as in lifting the smaller, so that the larger weight affects the acquired endurance mostly.

Since the second pause has proved proportionately more efficient as a rest period than the first, a series of observations were made with the intention of determining what might be the influence of a one-minute and a two-minute pause in a series of fatigue curves. The number of curves that were possible within the limits of our apparatus was six for the one-minute pause for both right and left hands, and three for the right hand with two-minute pause, and four for the left hand with a two-minute pause. M. alone made observations upon this point. The observations were equally divided between "exhaustion" and "not exhaustion," and the figures given in the following table are the averages of four records:

TABLE VIII

M. R. H.

| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | 4th Curve | % | 5th Curve | % | 6th Curve | % | 7th Curve | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Not-ex.. | 2424 | 861 | 100 | 304 | 35.2 | 233 | 27.1 | 316 | 36.5 | 251 | 29 | 233 | 27 | 228 | 26.4 |
| Exhaus. | 2301 | 833 | 100 | 316 | 37.9 | 285 | 34.2 | 229 | 27.4 | 233 | 28.5 | 211 | 25.3 | 191 | 22.8 |
| Differ... | 123 | 28 | ... | —12 | —2.7 | —52 | —7.1 | 87 | 9.1 | 13 | .5 | 22 | 1.7 | 37 | 3.6 |

M. L. H.

| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | 4th Curve | % | 5th Curve | % | 6th Curve | % | 7th Curve | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Not-exh.. | 2366 | 793 | 100 | 358 | 45.2 | 259 | 32.6 | 224 | 28.3 | 240 | 30.3 | 243 | 30.7 | 246 | 31 |
| Exhaust.. | 2153 | 988 | 100 | 226 | 22.8 | 244 | 24.6 | 211 | 21.3 | 180 | 18.3 | 154 | 15.5 | 151 | 15.3 |
| Difference | 213 | —195 | ... | 132 | 22.4 | 15 | 8 | 13 | 7 | 60 | 12 | 89 | 15.2 | 95 | 15.7 |

TABLE VIII—*Continued*

M. R. H. 2-MINUTE PAUSE

| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | 4th Curve | % |
|---|---|---|---|---|---|---|---|---|---|
| Not-exhaustion ..... | 2939 | 1118 | 100 | 646 | 57.7 | 627 | 56 | 582 | 52 |
| Exhaustion ..... | 2701 | 1138 | 100 | 568 | 49.9 | 511 | 44.9 | 483 | 42.4 |
| Differences ..... | 238 | —20 | .... | 78 | 7.8 | 116 | 11.1 | 99 | 9.6 |

M. L. H. 2-MINUTE PAUSE

| | Total | 1st Curve | % | 2d Curve | % | 3d Curve | % | 4th Curve | % | 5th Curve | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Not-exhaustion.. | 2758 | 972 | 100 | 510 | 52.4 | 480 | 49.3 | 465 | 47.8 | 330 | 33.3 |
| Exhaustion ..... | 2566 | 956 | 100 | 457 | 58.2 | 432 | 45 | 461 | 37.8 | 360 | 37.7 |
| Differences..... | 192 | 16 | .... | 53 | —5.8 | 48 | 4.3 | 4 | 10 | —30 | —4.4 |

The first part of the table giving the value of the one-minute pauses shows that while there are some fluctuations, the pause shows a decreasing efficiency for recuperative purposes. The

fatigue curves have grown gradually though not uniformly less in the succeeding curves.

There are several considerations to be made here. As the pause is too short to remove the hand and give it the best opportunity for rest, a very unfavorable disposition begins to arise. The hand becomes congested with blood, and muscle cramps are likely to manifest themselves. Even under the most favorable conditions, for instance, where the hand could be taken out and given the best opportunity to recuperate, the pause would be likely to show a decreasing efficiency for recuperation. To remove the hand would result in a loss of the incitation that comes with being warmed up to a task.

The observations were divided between the "exhaustion" and "not exhaustion" types, and with one or two exceptions the "not exhaustion" performances show a higher value for the rest period than the "exhaustion" performances. In the observations where a two-minute pause was allowed, the "not exhaustion" shows at an equal, or perhaps only a little advantage over the "exhaustion." Compared with the observations in which one-minute pause was allowed, the per cent of increase for the right hand is nearly twenty and somewhat less for the left. The unfavorable disposition created by the longer confinement of the hand in the fixating devices was greater, and the reagents found the experiments even more irksome than when a one-minute pause was allowed. The results of these observations are introduced rather to direct the attention to the problem here involved than on account of the value which they may have in themselves. They represent the last work that was done and would have been continued except for lack of time.

## SUMMARY

Ergograph records change relatively in the course of a long series and thus the first records in a series are invalidated, for maximum performances furnish a more reliable measure of work capacity.

Since exercise induces a condition within the muscles themselves which reduces their capacity for work, ergograph records

have slight validity until inurement has become thorough and coordination is complete.

Since the reagents must be fairly inured and the effects of exercise must be studied under the most exacting conditions and for long periods of time, the ergograph is quite unadapted to the obtaining of exact statistics upon a large number of individuals. Therefore a few records taken upon unpracticed subjects, both before and after operations whose influences are thought to affect muscular power, are without the slightest claims to trustworthiness.

Influences which are supposed to affect the ergograph records must be studied by the way they affect practice gain.

Practice gain with the ergograph is due to changes in the direction of inurement, coordination, rhythm, and endurance in muscular power.

Practice gain as shown by the ergograph is practically unlimited.

Fatigue is a necessary condition for practice gain. It is essential to growth.

Practice gain means increased power to recuperate.

Vicarious practice effect is chiefly in the direction of coordination and rhythm.

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# University Studies

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## I.—*On the Determination of the Refractive Indices by Means of Channeled Spectra*

BY S. R. WILLIAMS

If the light reflected from two parallel optical surfaces be examined with a spectroscope of sufficient resolving power, the resulting spectrum will be traversed by dark bands corresponding to those wave-lengths which interfere, the center of a dark band occurring when $2\mu D = 2N\lambda/2$ and the medium between the surfaces is of a less refractive index than that composing the optical surfaces. For the center of a light band $2\mu D = (2N+1)\lambda/2$ where $D$ is the linear thickness of the space intervening, $\lambda$ the wave-length, and $N$ some integral number. In case $\mu$ becomes equal to unity, as occurs when we have a vacuum, the value of $N$ in the above equation may be derived, giving the length of the path $D$ in wave-lengths of light. Using the sun as a source of light there will appear in the spectrum the Fraunhofer lines, in addition to the interference bands, thus furnishing a scale of reference for every interference band.

If two dark bands appear in determinate parts of the spectrum corresponding to wave-lengths $\lambda_1$ and $\lambda_2$, then by the above equations $2\mu_1 D = N\lambda_1$ for the longer wave-lengths, and $2\mu_2 D = (N+m)\lambda_2$ for the shorter, whence, assuming $\mu = 1$, we obtain $N = \frac{m\lambda_2}{\lambda_1 - \lambda_2}$.

University Studies, Vol. IV, No. 2, April, 1904.

A comparison of the results obtained by various investigators in the determination of refractive indices shows at once that the optical thickness can not be obtained by the above formulae for those substances in which $\mu$ is such an uncertain quantity.

Dr. D. B. Brace[1] has shown that the difference in path of two interfering rays, or the optical thickness, may be determined independently of the factor $\mu$. His method is to take a cell, whose thickness can be varied (usually a wedge-shaped cell), and if, in the variation of the thickness, $m$ bands are shifted past a definite point in the spectrum for which the difference in path $N$ is to be determined, and $n$ is the ratio of the bands between two definite wave-lengths, $\lambda_1$ and $\lambda_2$, before and after the variation in thickness, then $N=\frac{mn}{1-n}$.

Being able to determine the difference in path thus, we are furnished with the means for determining the value of $\mu$ for any transparent substance. For, if we take as a medium of reference a substance of index $\mu_r$, which is accurately known, $2\mu_r D = N_r\lambda$. In the body whose index is to be determined $2\mu_l D = N_l\lambda$. $D$ and $\lambda$ being made the same, we have $\mu_l = \frac{N_l}{N_r}\mu_r$, that is, the refractive index of any substance is equal to the ratio of the optical lengths of equivalent paths in that substance, and the medium taken as a reference, multiplied by the index of the reference film.

For liquids, the path $D$ may be easily made the same by making a thin wedge-shaped cell with its sides parallel, and allowing the light to be reflected from a narrow vertical section of the same. If the upper half of the narrow section reflects from the surfaces of the film taken as a reference, and the lower half from a substance whose index is to be determined, there will occur in the spectrum, simultaneously, two sets of interference bands from which the orders of interference may be calculated, and from these the index.

By the distribution of the two sets of bands thus obtained the dispersive power of the two substances may be compared, for if $\mu$ was larger in one than in the other, the bands would appear

[1] *Phil. Mag.* (48), 1899, p. 345; (1), 1901, p. 339.

more frequent throughout the spectrum as shown by our equation above. In this way the complete record of dispersion of a body may be obtained throughout the spectrum. Furthermore, the bands superimposed upon the Fraunhofer lines as a scale may be photographed and a permanent record made of the dispersion of the substance examined.

To make this a practical working method was the object of this investigation.

A four-inch Rowland concave grating, 14,438 lines to the inch, with Brashear mounting, and focal length of ten feet was used. Fig. 1 shows the arrangement of the optical system. The slit was illuminated by the direct rays of the sun, and an image of

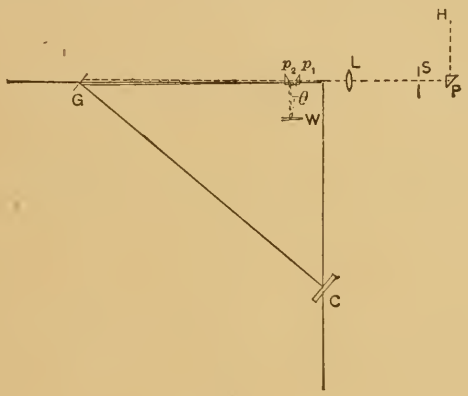



*Fig. 1*

the same was formed on the wedge *W* by the lens *L*. In the usual mounting of the Rowland concave grating, the slit or its image should be placed over the intersection of the ways, in order that the spectrum may be brought to a focus on the proper focal curve. Instead of doing this, the light coming from the slit *S* through the lens *L* was reflected by means of the prism $p_1$ upon the wedge *W*, where the image of the slit was formed. The two surfaces of *W* returned the light to the prism $p_2$, which reflected it upon the grating *G*. The distance of *W* from $p_1$ and $p_2$ was such that the image in $p_2$ was at the intersection of the ways, and thus the conditions for accurate focusing were

secured. The image of the slit at *W* served two purposes, in that it brought the Fraunhofer lines and interference bands into focus at the same time, and also afforded the means of getting a narrow vertical section of the cell.

Plate glass cut in strips, 3 x 13 cm. and 6 mm. thick, formed the sides of the wedge-shaped cell. To keep the plates apart, and also form the bottom and ends of the cell as well as the dividing strip between the films, cork strips about .75 mm. thick were cut out, as shown in fig. 2. The plates were then held firmly against this strip by means of clamps, those on one end being screwed down more tightly than the other, in order to make the cell wedge-shaped. The mounting of the cell was so arranged by means of a rack and pinion that it could be raised and lowered in a vertical direction, and also moved in the direc-

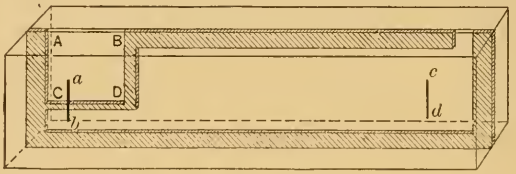



*Fig. 2*

tion of its length, by means of a micrometer screw. For photographing the two sets of bands simultaneously, the cell was so moved that the image of the slit occupied a position as *ab* in fig. 2.

*ABCD* is that part of the cell containing the film of reference, while the rest of the cell holds the liquid whose index is to be determined. The two sets of bands having been photographed together, the cell was moved parallel to its length, while the bands from the liquid film were counted as they moved past some fixed point in the spectrum, until the image of the slit occupied a position as *cd* in fig. 2. In this position a set of bands throughout the spectrum was photographed, and knowing the index for one wave-length, it could be determined for all others by counting the bands.

Air was used for a reference film. Its index has been very

accurately determined by means of the interferometer, and the presence of a vapor does not affect it, as it has been ascertained that the refractive index of dry air is only about one-millionth greater than air saturated with a vapor. The values, as found by various investigators, vary by little over one part in a million. Air has also been used as a medium of reference by other investigators, and so is used in this work.

The direction of variation in thickness of the cell is at right angles to the interference bands, since along their length the thickness must be uniform. They will be parallel to the Fraunhofer lines, then, when the refracting edge of the cell is parallel to the image of the slit. This was the means used for getting

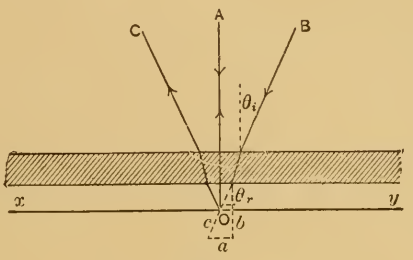



*Fig. 3*

the plates of the cell parallel in a vertical direction, for, if the interference bands were brought into coincidence above and below the dividing strip, before the liquid is introduced, the value of $D$ for both films must be the same.

Another condition necessary to give $D$ an equivalent path, in both films, is that the incidence be normal upon their surfaces, for, owing to refraction at the bounding surfaces, the ray will be bent more or less for one than the other, depending upon the difference in index, consequently $D$ would vary for the two films. In the system used, normal incidence was not possible, but it was made so small that it entered no appreciable error. Let $AO$, fig. 3, represent the path of normal incidence upon air film $xy$ contained between two plates. Let $BOC$ be the path of a ray at an incident angle of $\theta_i$. Since the film $xy$ is an air film, the angle of refraction at its surface will be the same as the angle of

incidence on the plate ( $\theta_i = \theta_r$ ); $\theta_r$ will also be a maximum for air. Hence if it can be shown that the angle $\theta_r$ does not produce an appreciable error in difference between $c$ and $b$, which are the lengths of $D$ at normal and oblique incidence, then it can be shown that for a ray incident at an angle $\theta_i$ upon two films, as an air and a liquid film, the difference in $D$ for the two is not an appreciable error, for the difference in the angle of refraction at the surfaces of the two films can never become as large as $\theta_r$; consequently the difference in length can never be as great as $c$-$b$ in the figure.

$$\tan \theta_r = a/b$$

$$\sin \theta_r = a/c$$

$$c - b = a\left(\frac{1}{\sin \theta_r} - \frac{1}{\tan \theta_r}\right)$$

$$\frac{c-b}{b} = \tan \theta_r\left(\frac{1}{\sin \theta_r} - \frac{1}{\tan \theta_r}\right) = \sec \theta_r - 1.$$

but $\frac{c-b}{b}$ is the per cent of error introduced. In the apparatus as set up, the light at prism $p_1$, fig. 1, was diaphragmed so that $\theta_r$ was about 25′. Substituting this value in the above equation, shows an error of about three parts in a hundred thousand. With light incident on two films the error due to difference of path $D$ is still less, as shown above.

In the liquid films with oblique incidence, dispersion produces a variation in $D$ for the different wave-lengths, so that if the index of the substance under examination be smaller than that of the containing cells, the path $D$ for the violet ray will be greater than that of the red, since it will be bent away from the normal more than the less refrangible wave-lengths. We have shown that difference in path, due to refraction, produced a negligible error, and since the angle of deviation is always less than the angle of refraction, no error in difference of $D$ for the various wave-frequencies will occur.

Again, the length of path $D$, as determined from the bands in the photographs, will be augmented by change of phase, at reflec-

tion from the bounding surfaces of the film, if the conditions of reflection for the two beams are not the same. In order to increase the intensity of light in reflection from the surfaces, a full-silvered surface was used at the back. After repeated trials, it was found that an approximate half-silvered front surface, which gave a brighter image of a flame by reflection than by transmission, produced the blackest bands in the channeled spectra.

O. Wiener[1] has found that the change of phase by reflection varies with the thickness of the silvering, increasing as a retardation from 0 to $3/4\lambda$, for all wave-lengths, as the thickness of silver increased from zero to a full silver.

The index of silver is about .25, so that in the cell that was used, if the half-silvering was placed on the rear surface of the front plate, and the full-silvering on the front surface of the rear plate, then for both films the condition of reflecting from a less refracting substance to a greater was secured for the two interfering rays.

According to Wiener, the half-silvered surface introduced a retardation of about $\lambda/2$, while at the rear surface it was $3\lambda/4$. This made the difference in phase of the two interfering rays greater by about $\lambda/4$, since the ray reflected from the back surface has been retarded that much more than the one reflected from the front surface. With the order of interference that was used in this work, this entered an error of less than three parts in one hundred thousand in determining the order.

In making the computation of indices, this change of phase was not regarded, and since, in photographing, the bands from the two films were brought into coincidence with the $D_1$ line, the orders of interference for these were regarded as an odd multiple of $\frac{\lambda_D}{2}$.

$(2N+1)\lambda/2=2\mu D$ then becomes the formula for finding the order of an interference band.

The cell was housed in a pasteboard box, which kept the temperature uniform during the photographing, so that the bands

[1] *Wied. Annal.* (31), 1887, p. 647.

did not shift due to that cause. The temperature was taken at the beginning of the series of photographs, and is indicated on the plates.

At times, a shift of the bands did occur, but this was due to a yielding of the cork strip between the plates or other mechanical effects. It was found that if the cell was allowed to stand before using, no difficulty was encountered from this source, for an eye-piece was attached to the side of the camera box, whose focus was on the focal curve of the grating, and through this the bands were watched, to see that they did not shift with respect to the Fraunhofer lines.

Mitchell[1] has shown that the astigmatism of a grating depends upon the length of the illuminated portion of the slit, the length of the ruled lines, and the angle which the incident light makes with the axis of the grating. On account of this property, comparison work is not possible as in the prismatic spectrum. In photographing the two sets of bands, comparison work was done, but other conditions were introduced that do not occur in ordinary comparison work. The light falling upon a grating was slightly divergent, and the dividing strip in the cell cut out a narrow section of light across the middle of the ruled portion of the grating. The light above this dark strip came from one film, and that below from the other. The length of ruling that was producing the spectrum for one set of bands was therefore less than half the actual length of ruling of the grating, and as a result the interference bands, from one film, extended about half the width of the spectrum.

If $D$ is the thickness, $\mu$ the index, $\lambda$ the wave-length, and $N$ the order of interference, the distribution of the bands throughout the spectrum is represented by the equations,—

$$(1)\quad N=\frac{2\mu D}{\lambda}$$

$$(2)\quad N=\frac{2D}{\lambda}\ \text{where}\ \mu=1,\ \text{as for a vacuum.}$$

[1] Johns Hopkins Univ. Circulars, June, 1898.

Differentiating these we have,

$$(3)\quad \frac{dN}{-d\lambda}=\frac{2D}{\lambda^2}\left(\mu+\lambda\frac{d\mu}{-d\lambda}\right)$$

$$(4)\quad \frac{dN}{-d\lambda}=\frac{2D}{\lambda^2}$$

Equations (1) and (2) are the equations of an equilateral hyperbola, $N$ and $\lambda$ being the variable parameters. In (3) and (4) the left-hand side of the equation represents the number of bands between wave-lengths $\lambda$ and $\lambda-\delta\lambda$, and is expressed on the right-hand side in terms of $D$, $\lambda$, and $\mu$. The variation of the order with wave-lengths in the two equations (3) and (4) differs by the factor in parenthesis, which expresses the difference in variation between the two sets of bands. Since in the two equations $\frac{2D}{\lambda^2}$ appears, which is the expression for the variation of order due to wave-length alone, if we superimpose a set of bands, e. g., those in a vacuum, whose variation is represented by (4), upon a set of bands represented by (3), the differential effect will be that due to the dispersion of the substance whose bands are represented by (3). To do this, the bands from the two films are brought into coincidence, say in the less refrangible portion of the spectrum. If, now, we go toward the violet, the bands in the spectrum whose variation is represented by (3) will, in general, increase in number more rapidly than those used as a scale. Consequently they will get out of coincidence. If then they should come into coincidence again, due to the bands not increasing so rapidly as those on the scale, the term in parenthesis must diminish, which indicates anomalous dispersion. In a subsequent paper it will be shown more in detail how this method may be used for the detection of this characteristic.

Preliminary work has been done in adapting this method to the determination of refractive indices of solids. The optical system was, in general, the same as used in working with liquids. The difficulty with solid wedges is to get a reflecting surface for the wedge and an equivalent film of air. If silvered plates be placed on both sides of the solid wedge, as for the liquid film, it

is impossible to get the plates in close enough contact to the wedge so as not to have thin air films intervening. This difficulty was overcome by measuring these air films, and thereby obtaining the equivalent film of air for reference. In fig. 4 is shown a vertical cross-section of the cell used in getting the order of interference in the wedge and an equivalent film of air. *W* is the solid wedge between two glass plates, silvered as they were in the liquid cell described above. The path of the light at *A* gives the total thickness of air space, *B* that of the wedge and air films on both sides. By properly silvering the lower part of the wedge, the interference bands due to the wedge itself

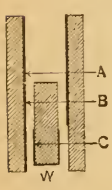


*Fig. 4*

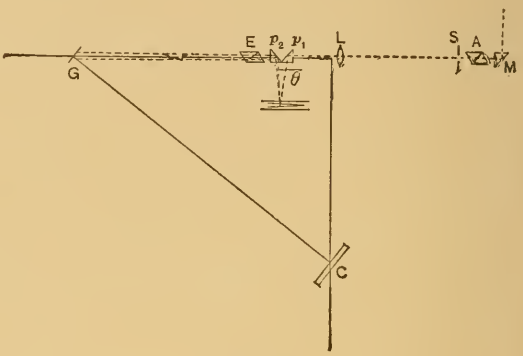


*Fig. 5*

may be obtained in C. *B*—*C* gives the thickness of the air films on the two sides of the wedge. *A*—(*B*—*C*) gives the thickness of an air film equivalent to the wedge. Consequently $\frac{C}{A-(B-C)}$ gives the index as compared with air. It was impossible to get the three sets of bands simultaneously, but *A* and *B* were first obtained and photographed, and then by means of rack and pinion the cell was raised and *B* and *C* obtained.

With proper adjustments, there was no shift of the bands in raising the cell vertically, since its sides and that of the wedge are parallel in that direction.

In solids showing double refraction, the optical system was arranged as shown in fig. 5, with a nicol, *A*, before the slit and another one, *E*, between the prism $p_2$ and the grating.

If a ray of light, polarized at an angle of 45° to the principal axis of a crystalline wedge, pass normally through and is reflected back again, the emergent light, when resolved by a spectroscope, will be traversed by interference bands due to double refraction in addition to the ordinary bands arising from the wedge. The superposition of the two sets of these latter bands gives rise to maximum and minimum in the intensity, producing the bands from double refraction referred to. The formula for these minima, when the nicols are crossed, is $N=\frac{2D(\mu_e+\mu_o)}{\lambda}$. In this way both the bands due to interference between the beams reflected between the front and back surface and those due to differential double refraction may be photographed.

With double refracting crystals, the system of reflection at $p_1$ and $p_2$ had to be changed, and is shown in fig. 5. In using the prisms $p_1$ and $p_2$ only, there would be a change of phase between the component vibrations. By using a double system of reflection, at right angles to each other, as shown in the cut, the two components will have practically the same change of phase introduced. This double reflection will place the image of the slit in a horizontal position, which necessitates turning the wedge so that its length is at right angles to the image of the slit.

Plate I is a series of photographs for triple distilled water. The photographs are arranged with the shorter wave-lengths to the left. In each set of photographs No. 4 was the first setting made in the spectrum, and is that of the liquid and air bands together, between the Fraunhofer lines, $\beta_2$ and $D_1$. No. 3 was taken in the same portion of the spectrum, after shifting several hundred bands. The others were taken in the order 5, 6, 2, 1.

In plate I the number of air bands between $\beta_2$ and $D_1$ is 276.6 from which the order 1978.5 for the Fraunhofer line $D_1$ is obtained by the formula $N=\frac{m\lambda_2}{\lambda_1-\lambda_2}$. In the liquid bands there are 374.7 between these two wave-lengths, and after shifting 338 bands past the $D_1$ line in the spectrum and photographing again, there are by count 326.7 bands in this same region. Substituting

these values in our equation $N=\frac{m\,n}{1-n}=\frac{338\times\frac{326.7}{374.7}}{\frac{48.}{374.7}}=2300.5$.

The order as found for the liquid is that of the $D_1$ line in photograph No. 3. For the $D_1$ line in No. 4 we add 338 to 2300.5 = 2638.5. The ratio between these two orders,

$$\frac{N\,\text{liquid}}{N\,\text{air}}=\mu=\frac{2638\ 5}{1978.5}=1.3336.$$

For the $D_1$ line in No. 3, the order for air would be the order for liquid at that point, divided by the index,

$$\frac{2300.5}{1.3336}=1725.0.$$

From these two orders of air and liquid for the $D_1$ line, the orders for all other points in the spectrum may be calculated and counted from the photographs.

In counting the bands, they were laid on a dividing engine under a micrometer eye-piece, and as the photographs were shifted under the cross wires, the bands were counted, the fractional part of a band being estimated only to tenths.

The results from all of the photographs shown were obtained in the manner described above and are tabulated below.

PLATE I—TRIPLE DISTILLED WATER. $m$=338. TEMP. 22°.

| λ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1480.9 | 1971.1 | 1.3310 |
| 6.5630 " " | 1549.9 | 2063.8 | 1.3316 |
| 5.8961 " " | 1725.0 | 2300.5 | 1.3336 |
| 5.6169 " " | 1810.7 | 2416.9 | 1.3348 |
| 5.3283 " " | 1908.7 | 2549.2 | 1.3356 |
| 5.2270 " " | 1945.8 | 2599.4 | 1.3359 |
| 5.1728 " " | 1966.2 | 2627.4 | 1.3363 |
| 4.9577 " " | 2051.4 | 2743.8 | 1.3375 |
| 4.8615 " " | 2092.1 | 2799.4 | 1.3381 |
| 4.6680 " " | 2178.7 | 2917.6 | 1.3391 |
| 4.3837 " " | 2320.1 | 3111.0 | 1.3409 |
| 4.2269 " " | 2406.2 | 3228.5 | 1.3417 |
| 4.1019 " " | 2479.5 | 3330.5 | 1.3432 |
| 3.9686 " " | 2562.6 | 3445.0 | 1.3443 |

PLATE II—ABSOLUTE ALCOHOL. $m$=393. TEMP. 22°.

| λ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1268.0 | 1721.0 | 1.3572 |
| 6.5630 " " | 1326.4 | 1802.1 | 1.3586 |
| 5.8961 " " | 1476.2 | 2009.5 | 1.3612 |
| 5.6169 " " | 1549.5 | 2111.5 | 1.3627 |
| 5.3283 " " | 1633.4 | 2227.5 | 1.3637 |
| 5.2270 " " | 1665.1 | 2271.5 | 1.3642 |
| 5.1728 " " | 1682.5 | 2296.0 | 1.3646 |
| 4.9577 " " | 1755.5 | 2397.7 | 1.3655 |
| 4.8615 " " | 1790.3 | 2446.3 | 1.3664 |
| 4.6680 " " | 1864.4 | 2550.4 | 1.3679 |
| 4.3837 " " | 1985.5 | 2721.3 | 1.3705 |
| 4.2269 " " | 2059.1 | 2825.1 | 1.3720 |
| 4.1019 " " | 2121.9 | 2913.5 | 1.3731 |
| 3.9686 " " | 2193.0 | 3014.5 | 1.3746 |

PLATE III—α-MONOBROMONAPHTHALIN. $m$=475. TEMP. 24°.

| λ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1440.1 | 2374.0 | 1.6485 |
| 6.5630 " " | 1507.2 | 2489.2 | 1.6515 |
| 5.8961 " " | 1677.5 | 2787.5 | 1.6617 |
| 5.6169 " " | 1760.9 | 2934.6 | 1.6665 |
| 5.3283 " " | 1856.2 | 3103.6 | 1.6720 |
| 5.2270 " " | 1892.2 | 3168.2 | 1.6743 |
| 5.1728 " " | 1911.0 | 3204.1 | 1.6767 |
| 4.9577 " " | 1994.9 | 3354.9 | 1.6817 |
| 4.8615 " " | 2034.5 | 3427.5 | 1.6847 |
| 4.6680 " " | 2118.7 | 3584.6 | 1.6918 |
| 4.3837 " " | 2256.2 | 3844.7 | 1.7034 |
| 4.2269 " " | 2339.5 | 4007.6 | 1.7130 |
| 4.1019 " " | 2411.2 | 4149.7 | 1.7210 |
| 3.9686 " " | 2492.1 | 4322.5 | 1.7345 |

PLATE IV—OIL OF CINNAMON (CASSIA). $m$=273. TEMP. 25.5°.

| λ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1229.0 | 1919.1 | 1.5615 |
| 6.5630 " " | 1286.3 | 2014.2 | 1.5659 |
| 5.8961 " " | 1431.6 | 2257.5 | 1.5769 |
| 5.6169 " " | 1502.7 | 2379.3 | 1.5833 |
| 5.3283 " " | 1584.0 | 2519.0 | 1.5903 |
| 5.2270 " " | 1614.8 | 2572.5 | 1.5937 |
| 5.1728 " " | 1631.7 | 2602.4 | 1.5949 |
| 4 9577 " " | 1702.4 | 2728.0 | 1.6024 |
| 4.8615 " " | 1736.2 | 2788.5 | 1.6061 |
| 4.6680 " " | 1808.1 | 2920.0 | 1.6149 |
| 4.3837 " " | 1925.5 | 3141.0 | 1.6312 |
| 4.2269 " " | 1997.0 | 3283.5 | 1.6437 |
| 4.1019 " " | Absorption, no | bands visible. | |
| 3.9686 " " | " " | " " | |

PLATE V—BENZOLE. $m$=235. TEMP. 22°.

| λ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1298.7 | 1924.9 | 1.4822 |
| 6.5630 " " | 1359.2 | 2017.7 | 1.4844 |
| 5.8961 " " | 1512.8 | 2254.4 | 1.4902 |
| 5.6169 " " | 1588.0 | 2371.6 | 1.4934 |
| 5.3283 " " | 1673.9 | 2505.4 | 1.4967 |
| 5.2270 " " | 1706.4 | 2556.4 | 1.4981 |
| 5.1728 " " | 1724.3 | 2584.4 | 1.4988 |
| 4.9577 " " | 1799.0 | 2702.5 | 1.5022 |
| 4.8615 " " | 1834.7 | 2758.9 | 1.5037 |
| 4.6680 " " | 1910.6 | 2880.4 | 1.5076 |
| 4.3837 " " | 2034.7 | 3079.4 | 1.5134 |
| 4.2269 " " | 2110.2 | 3202.8 | 1.5177 |
| 4.1019 " " | 2174.5 | 3308.4 | 1.5214 |
| 3.9686 " " | 2247.4 | 3429.4 | 1.5259 |

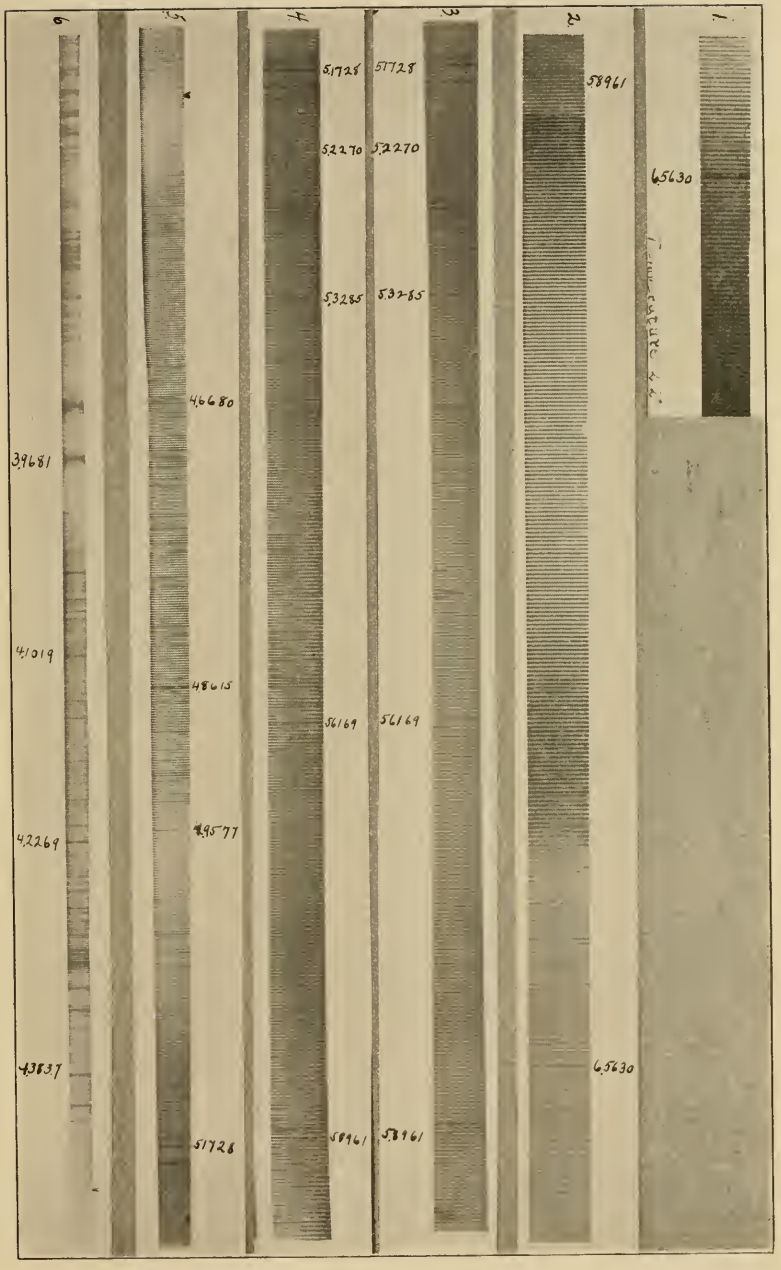
PLATE VI—OLIVE OIL. $m$=267. TEMP. 26°.

| $\lambda$ CMS. | $N$ AIR | $N$ LIQUID | INDEX |
|---|---|---|---|
| 6.8674 x $10^{-5}$ | 1190.3 | 1721.0 | 1.4458 |
| 6.5630 " " | 1245.7 | 1802.1 | 1.4474 |
| 5.8961 " " | 1386.5 | 2012.5 | 1.4514 |
| 5.6169 " " | 1455.4 | 2116.5 | 1.4542 |
| 5.3283 " " | 1534.2 | 2234 5 | 1.4565 |
| 5.2270 " " | 1564.0 | 2279.5 | 1.4567 |
| 5.1728 " " | 1580.3 | 2304.2 | 1.4581 |
| 4.9577 " " | 1648.8 | 2407.6 | 1.4602 |
| 4.8615 " " | 1681.5 | 2457.5 | 1.4615 |
| 4.6680 " " | 1751.1 | 2563.5 | 1.4639 |
| 4.3837 " " | 1864.9 | 2733.0 | 1.4655 |
| 4.2269 " " | 1934.0 | 2839.5 | 1.4682 |
| 4.1019 " " | 1992.9 | 2930.6 | 1.4705 |
| 3.9686 " " | 2059.8 | 3034.5 | 1.4732 |

One of the difficulties met with in this method is the shifting of the bands during the photographing, as occurs in all interference work. This was mechanical, and was overcome by shifting the cell, for all the shift of the bands with respect to the Fraunhofer lines originated in the cell itself. That the Fraunhofer lines and interference bands appear simultaneously is one of the important features of this method. No matter what apparatus is used, the scale of the Fraunhofer lines will always be the same from which the measurements are made, and no mechanical errors can enter. The shift of bands which might arise due to changes of temperature must be guarded against in all methods.

It is also possible with the normal spectrum to determine directly the index for any wave-length. In the prism method, we are dependent upon the more prominent Fraunhofer lines for points of reference.

PLATE I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5.8961
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3.9681
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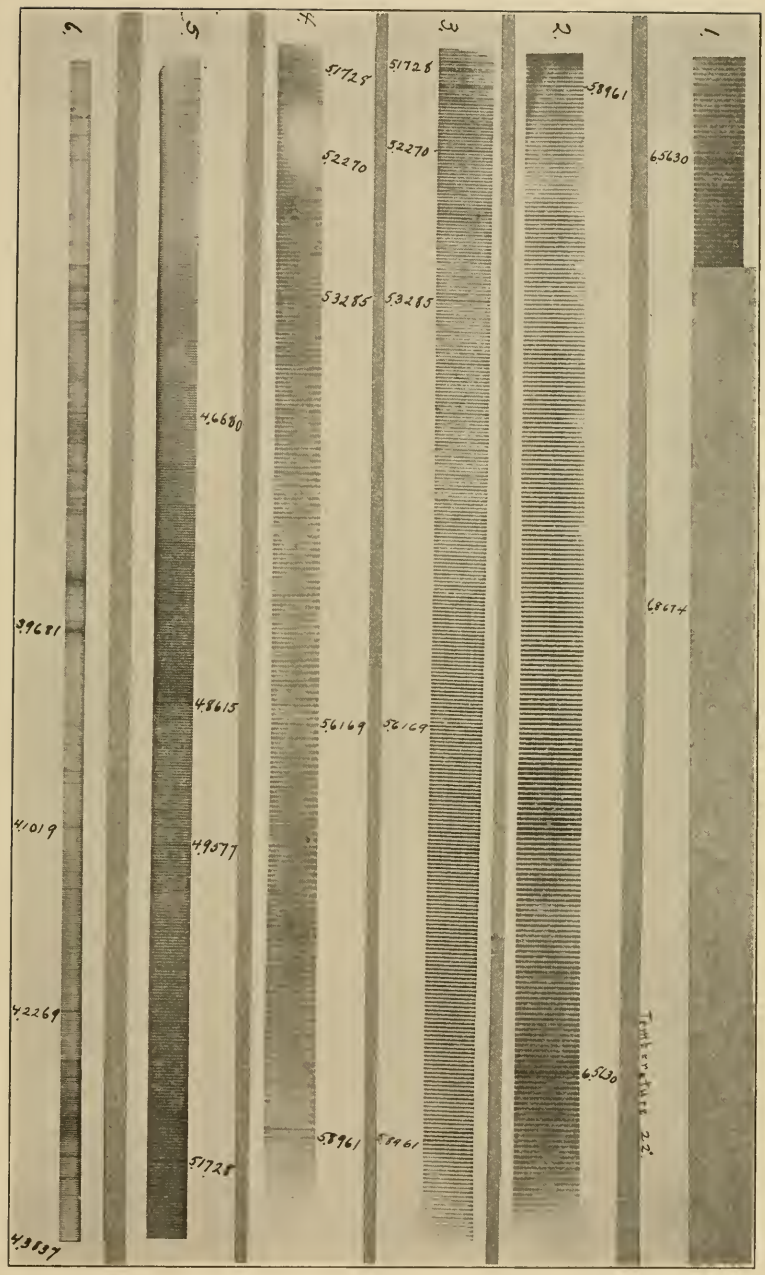
5.8961

PLATE II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51728
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49577
51725
39681
41019
42269
43937
Temperature 22°

PLATE III

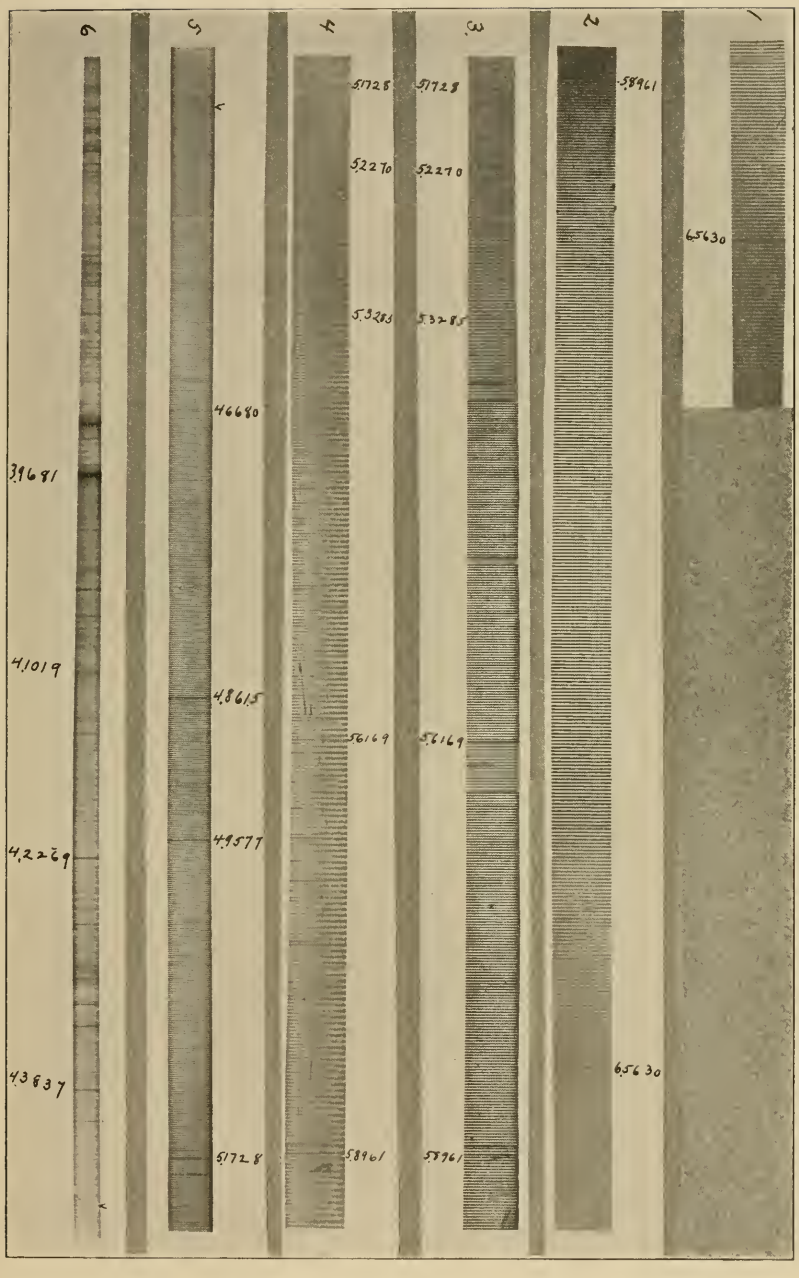
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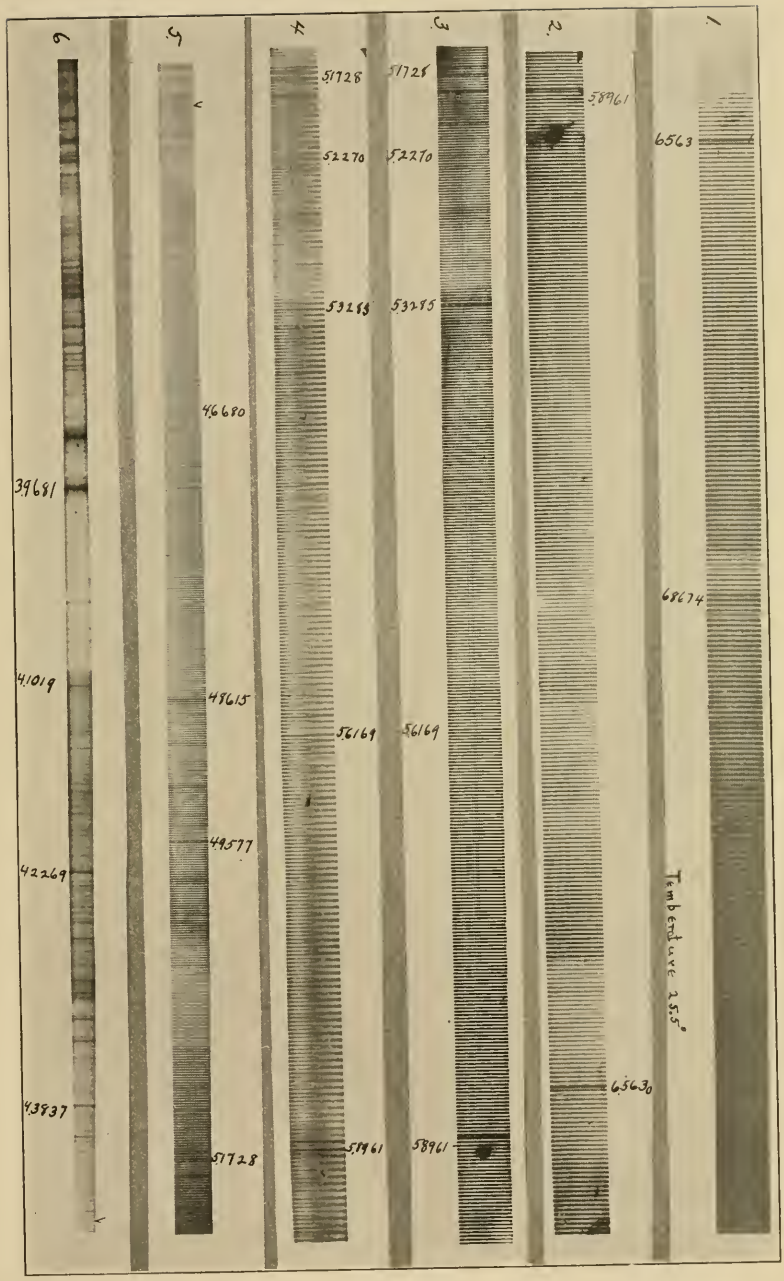
PLATE IV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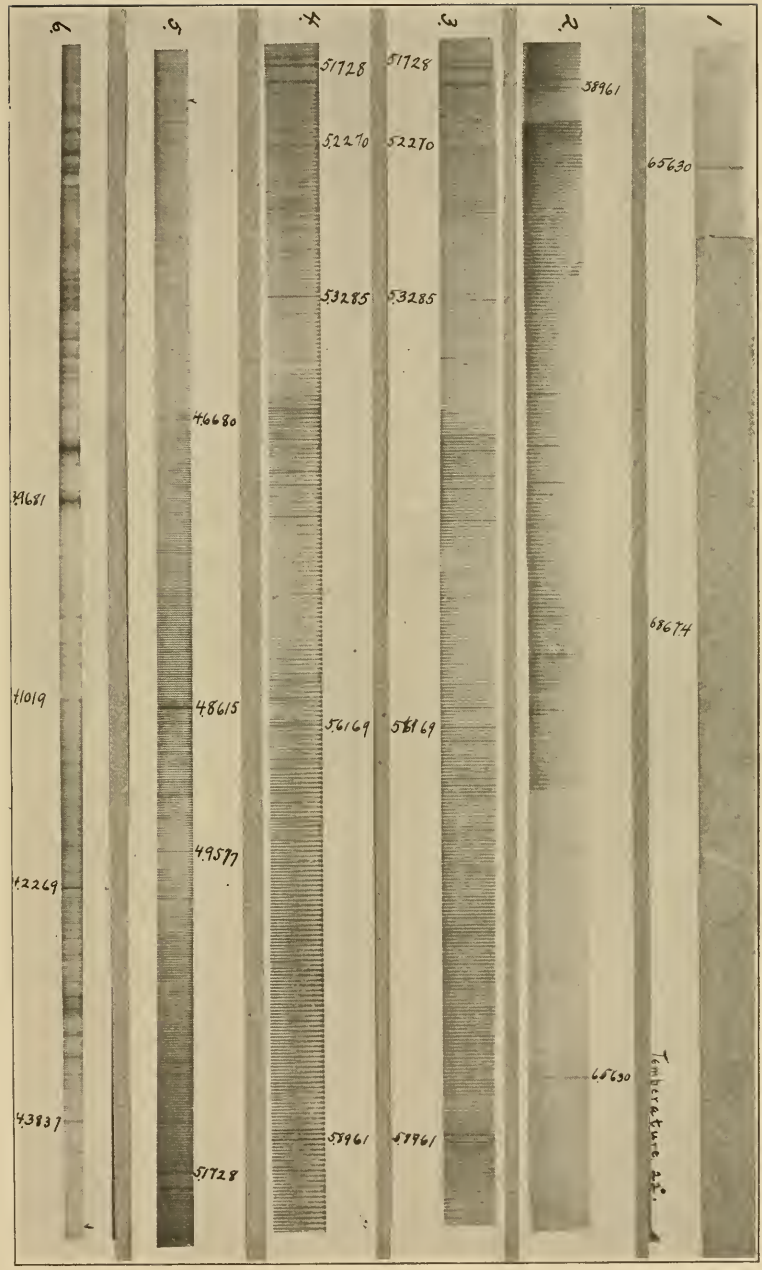
Temperature 25.5°

PLATE V



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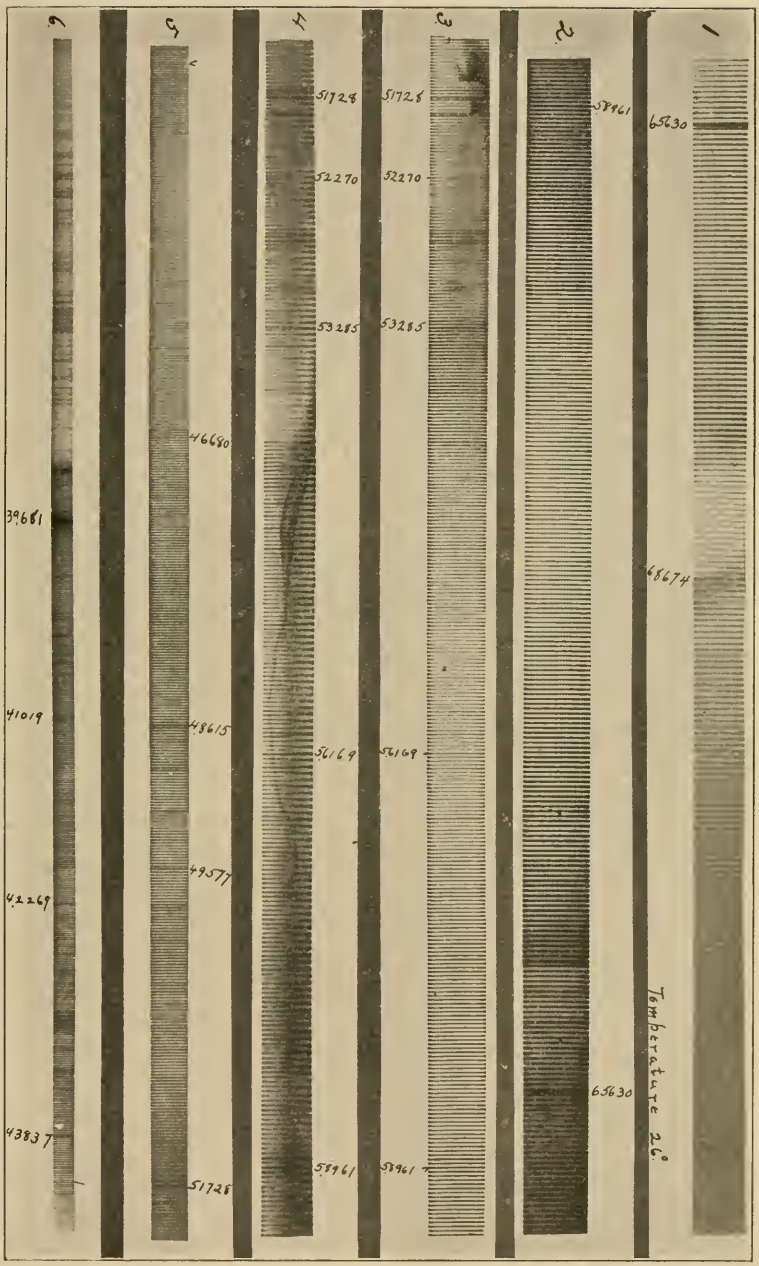
Temperature 22°.

PLATE VI


6
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51728
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56169
58961
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52270
53285
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58961
58961
65630
65630
68674
Temperature 26°

## II.—*On the Effect of a Magnetic Field on the Interference of Natural Light*

BY JOHN MILLS

The fundamental principles stated by Fresnel and Arago of the interference phenomena of plane polarized light are well enough known. In the case of natural light our conception is that it is an elliptically polarized vibration, where the major axes of the ellipse assume in a very short space of time all the possible azimuths, and the eccentricity of the ellipse is at the same time undergoing continuous changes. We further conceive of this elliptical vibration as capable of resolution into two straight line components at right angles to each other and in no way correlated. In the interference of natural light under ordinary conditions we may look upon the phenomenon as produced by the superposition upon an ether particle of two sets of the component parts of an ellipse, where the two components of the same kind are acting in directions parallel to each other. The rotation of the ellipse as a whole through 90° would bring like components into a position at right angles to each other, and interference phenomena should then disappear.

In an article by L. Sohncke[1] the statement is made that Abbe had noticed in his investigations that natural light was capable of rotation by natural rotatory substances in a way entirely analogous to the rotation of plane polarized light. In the path of one ray of an interfering system he had placed a piece of right-handed quartz capable of producing a rotation in the case of plane polarized light of 45°, in the path of the other ray a similar piece of left-handed. The rotation thus brought about of the two beams through an angle of 90° with respect to each other caused

[1] Sohncke, *Über electromagnetische Drehung natüralischen Lichts*, Wied. Ann. 27, p. 206, 1886.

University Studies, Vol. IV, No. 2, April, 1904.

the disappearance of the interference phenomena previously observable. The addition of two similar pieces producing a difference of 180° caused their reappearance.

The discovery of the electromagnetic rotation of plane polarized light by Faraday was followed by many investigations in that line. The question as to whether an electromagnetic field influenced natural light in a manner analogous to its rotation of plane polarized light was first set forth by Sohncke in the paper previously referred to. In a paper on the nature of the Faraday effect D. B. Brace[1] had already remarked that in the case of elliptically polarized light—that is more nearly approaching the form of vibration of natural light than either plane or circularly polarized—the interference bands became less distinct upon the formation of an electromagnetic field in the medium. By an interference system similar to that of the fundamental interference experiment of Young, Sohncke found that natural light was capable of rotation in an electromagnetic field.

His method was as follows: Light from a single slit was allowed to fall upon a screen with two small slits close together. Upon the further side of this screen and at a suitable distance interference bands were observable. By placing behind this double slit a Soleil double quartz plate of the proper thickness and allowing the light from one slit to pass through one side of the plate, while the light from the other slit passed through the other side, there was brought about a rotation of the components of the light used through an angle of 90° and the consequent disappearance of the interference bands. In the path of one of these interfering rays and between the screen and the observer was placed a parallelopiped of Faraday glass surrounded by a coil. In the path of the other ray was placed a similar plate and coil, but drawn back along the line of the beam far enough to allow of the formation of independent electromagnetic fields. For the strength of current used a rotation of 9.2° was possible in each coil. The coils were so connected as to give twice the rotation possible for one coil. If, then, natural light is capable of an

[1] *Wied. Ann.* 26, p. 576, 1885.

electromagnetic rotation, the making of the current circuit should cause the reappearance of the interference fringes. Such was the phenomenon observed by Sohncke.

The writer has recently been using a form of apparatus[1] which suggested the further verification of this work in a somewhat different manner. The apparatus used consisted of the more general type of the Michelson interferometer, in the path of each ray of which was placed a tube of carbon bisulphide surrounded by a coil and supported independently of the coil. The coils were connected so as to produce a rotation in the case of plane polarized light in opposite directions in the two tubes. The source used was sodium light. If natural light is capable of rotation in an electromagnetic field, varying the current should cause the interference bands to pass through alternate maxima and minima of intensity. The positions of the minima should then correspond to the times at which the current would produce in the two tubes a rotation of an odd multiple of 90°.

Plane polarized light in passing through one coil was found to be rotated 90° by a current of 13.06 amperes. In the case of the other this was found to be 13.23 amperes. The mean of these two values should give the current necessary in both coils if acting in opposite directions to produce a rotation of 180°.

Using the apparatus described, a series of readings were taken as follows: A rheostat in the circuit was adjusted, increasing the current until the quantity passing through the coils was just sufficient to cause the disappearance of the bands; at this point the ammeter reading was taken by an assistant. The current was then increased until the bands reappeared. The motion of the lever arm of the rheostat was then reversed and the current decreased until they again disappeared; at this point a second reading was taken. The mean of these two readings should give the value of the current for which the fringes were entirely invisible. The point of disappearance of the bands it was found could most easily be ascertained by the following device. The compensating plate of the interferometer was mounted on a brass

[1]The apparatus used was that granted to Messrs. Morley and Miller by the A. A. A. S. See *Phys. Rev.* 7, p. 283, 1898.

support. To this a lever arm was attached. Applying a slight pull to this arm produced a torque on the support which varied the length of path of one beam, and so caused the fringes to move across the field. By this slight motion their presence could be recognized after they were otherwise indiscernible.

A series of these readings appears below. In the following table it is to be noted that the mean of the first two columns would give the current flowing in each coil. Twice this mean would give the current necessary to produce the same effect if only one coil was causing rotation.

TABLE I—For a Rotation of 90°

| UPPER VALUE OF CURRENT | LOWER VALUE | EQUIVALENT CURRENT FOR ONE COIL | CORRESPONDING ROTATION |
|---|---|---|---|
| 7.8 | 6.4 | 14.2 | 97.24° |
| 7.8 | 6.25 | 14.05 | 96.20 |
| 7.8 | 6.3 | 14.1 | 96.56 |
| 7.75 | 6.45 | 14 | 95.86 |
| 7.75 | 6.45 | 14.2 | 97.24 |
| 7.4 | 6.45 | 13.85 | 94.86 |
| 7.7 | 6.3 | 14 | 95.86 |
| 7.7 | 5.8 | 13.5 | 92.44 |
| 7.4 | 6.4 | 13.8 | 94.53 |
| 7.7 | 6.4 | 14.1 | 96.56 |
| | | | Mean 95.73° |

TABLE II—For a Rotation of 270°

| UPPER VALUE OF CURRENT | LOWER VALUE | EQUIVALENT CURRENT FOR ONE COIL | CORRESPONDING ROTATION |
|---|---|---|---|
| 19 | 18.7 | 37.7 | 258.2° |
| 19 | 18.6 | 37.6 | 257.5 |
| 19.1 | 18.6 | 37.7 | 258.2 |
| 18.9 | 18.6 | 37.5 | 256.8 |
| 18.9 | 18.4 | 37.3 | 255.7 |
| 19.2 | 18.5 | 37.7 | 258.2 |
| 19 | 18.8 | 37.8 | 258.9 |
| 18.8 | 18.6 | 37.4 | 256.2 |
| 19 | 18.6 | 37.6 | 257.5 |
| 19 | 18.5 | 37.5 | 256.8 |
| | | | Mean 256.8° |

TABLE III—For a Rotation of 450°

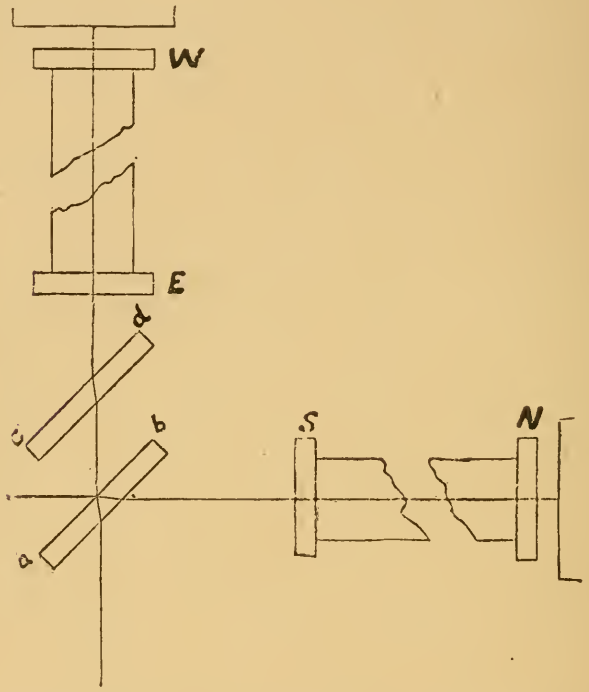
| UPPER VALUE OF CURRENT | LOWER VALUE | EQUIVALENT CURRENT FOR ONE COIL | CORRESPONDING ROTATION |
|---|---|---|---|
| 32 | 32.5 | 64.5 | 441.8° |
| 32 | 33 | 65 | 445.1 |
| 32.5 | 33.5 | 66 | 452 |
| 32 | 33 | 65 | 445.1 |
| 33 | 33 | 66 | 452 |
| 32.5 | 33 | 65.5 | 448.5 |
| 32.5 | 33 | 65.5 | 448.5 |
| 32 | 33 | 65 | 445.1 |
| 32 | 33 | 65 | 445.1 |
| 32.5 | 33.5 | 66 | 452 |
| | | | Mean 447.5° |

TABLE IV—For a Rotation of 630°

| UPPER VALUE OF CURRENT | LOWER VALUE | EQUIVALENT CURRENT FOR ONE COIL | CORRESPONDING ROTATION |
|---|---|---|---|
| 44 | 44.5 | 88.5 | 606.0° |
| 45 | 45 | 90 | 616.3 |
| 45.5 | 46 | 91.5 | 626.6 |
| 45 | 45 | 90 | 616.3 |
| 44.5 | 45 | 89.5 | 612.8 |
| 45 | 48 | 93 | 636.7 |
| 44 | 45 | 89 | 609.6 |
| 43 | 45 | 88 | 602.7 |
| 44 | 44 | 88 | 602.7 |
| 44 | 44.5 | 88.5 | 606 |
| | | | Mean 613.6° |

In consideration of the fact that the observations of Sohncke were made for a rotation of only 9.2° in each coil, it seemed worth while to make use of the apparatus mentioned above to carry out that investigation for some 720°. In the work of Sohncke, however, a type of interference system was used which involved no reflecting surfaces. At first glance it would seem that the results obtained from the present form of the experiment were vitiated by the use of plates giving reflections. It is true that a portion of the light passing through the coils will be po-

larized. If, however, the plane polarized portions of the two beams which go to form the fringes have been rotated through an angle of an odd multiple of 90° with respect to each other, the fringes previously due to them will disappear. Interference phenomena due to the natural light portions of the same beams would still be observable unless these also had suffered a similar rotation.




In the form in which the observations given above were taken each tube was susceptible at the point of a minimum of rotation of an odd multiple of 45°. Of the light entering the interferometer (see the accompanying figure) a portion of that reaching tube *EW* is plane polarized by reflection from the dividing surface[1] *ab* and by transmission through the compensating plate *cd*.

[1] In the present form of the interferometer the dividing surface of *ab* was used unsilvered.

Upon emerging its plane has been rotated 45°. The greater part of that entering tube *NS* is unaffected until by its final transmission and reflection at *ab* a portion of it is polarized in the same plane as that entering *EW*. If, however, the natural light in traversing the coil *NS* was rotated through 45° the portion of it which suffered polarization at *ab* would be resolvable into two components at right angles, one of which would be at an angle of 90° to the rotated polarized light emerging from the tube *EW* and so incapable of interference. The remaining portions of the light entering the observing telescope composed of natural light would have been rotated 45° in each coil and would also be incapable of interference. The criterion, then, for the rotation of natural light is, in the present form of experiment, the disappearance of all the fringes previously observable.

The question now arises as to whether or not the fringes formed by the natural light are of sufficient intensity to be visible if no rotation of natural light should occur. If the portion of natural light entering the field of the telescope is sufficiently large for the fringes formed by it to be observable when the other portion of the light fails to interfere, the method used seems sufficiently rigorous. The amount of unaffected light as found by the formulae of Fresnel was some .26 of all the light capable of forming interference bands. To find the minimum value that this quantity could have and still be observable, a series of readings was taken for plane polarized light in the following manner: A field was produced in only one coil. The current was then increased until the fringes vanished. The current was then varied until they reappeared; at this point the reading was taken. The angle as calculated for the rotation corresponding to the difference between the value of the current at which the fringes were visible and that at which they were entirely extinct gave a measure of the sensitiveness of the present arrangement. It was found as a mean of several readings that fringes formed by 0.06 of the total light could be recognized. The criterion then, as stated above, for the rotation of natural light was the disappearance of all the fringes previously observable.

# III.—*Some Hypermetamorphic Beetles and Their Hymenopterous Hosts*

BY W. DWIGHT PIERCE

## Introduction[1]

The accompanying paper is the result of the study of the life-history of certain beetles. These beetles are parasites upon Orthoptera and Hymenoptera. As a result of this parasitic habit their metamorphosis is prolonged and modified, occasioning that series of supernumerary changes which is designated as hypermetamorphosis. The study of the group brings out many interesting points in the life cycle of such parasites. In the discussion of the hosts of these beetles interesting notes are also recorded concerning their life-history and economy, and additional records are given of other parasites on the same hosts, indicating a great whirlpool of parasitism.

The treatise is divided into three distinct sections. Part I is a systematic account of the hypermetamorphic beetles as a whole, and includes descriptions and tables. Part II is a biological study of the life-history of one of these beetles (*Myodites solidaginis*), so far as the personal observation of the writer has reached. Part III is a biological study of the conditions existing in the homes of the host of the beetle (*Epinomia triangulifera*).

The author's acknowledgments are due to Professors L. Bruner and R. H. Wolcott, to Mr. Myron Swenk of the University of Nebraska, and to Mr. J. C. Crawford, Jr., of West Point,

[1] Notice to Bibliographers. This paper includes important notes on several subjects and should be indexed by cross-references. The author does not wish to be presumptuous, but thinks that it would be of considerable aid to those working on the subjects if the article were indexed under its subtitles. For this reason the following references are suggested as important: Nebraska, Parasitism, Hypermetamorphosis, Meloidae, Myodites, Rhiphiphorus, Stylops, Xenos, Apoidea, Vespoidea.

Neb., for valuable advice and information. Mr. Crawford and Mr. Swenk have both furnished lists of bees that visit certain host plants and those that might be implicated in other ways. Mr. Crawford has also furnished specimens and determinations, in addition to assisting in deciphering several of the problems. Acknowledgments are also due to various members of the UNIVERSITY STUDIES committee for aiding toward a concise statement of the facts embodied.

## PART I

### THE HYPERMETAMORPHIC BEETLES

Under this grouping we place those three families of Heteromera, Meloidae, Rhipiphoridae, and Stylopidae, which undergo hypermetamorphosis and are parasitic in the larva form at least.

Heteromera is defined by Le Conte as having the front and middle tarsi 5-, and hind tarsi 4-jointed. In Stylopidae will be found exceptions to this rule which the author thinks, however, due to parasitism. Their natural position is assuredly with the three above named families. Heteromera is first divided as to whether the coxal cavities are closed or open behind. The families under consideration have them open.

The next division is as to the constriction of the head at its base. The families Monommidae, Melandryidae, Pythidae, and Oedemeridae do not have the head strongly and suddenly constricted at the base. The remainder of the families have the head strongly constricted at the base. The Cephaloidae have the head prolonged behind and gradually narrowed.

Mordellidae have the lateral suture of the thorax distinct; this is also true of the Evaniocerini in the Rhipiphoridae. The other families lack the lateral suture. In Mordellidae the antennae are filiform, 11-jointed, and usually slightly thickened externally, and the elytra are narrowed behind, exposing the tip of the abdomen, though not truncate.

Anthicidae have the hind coxae not prominent; the antennae 11-jointed, nearly filiform, and rarely flabellate.

Pyrochroidae have the hind coxae prominent, the claws simple, and the head horizontal. The antennae are 11-jointed, serrate or subpectinate in the female, and ramose in the male, very nearly filiform.

The preceding families have normal metamorphosis so far as known, are found on plants, and are not parasitic. The three remaining families have hypermetamorphosis, and although the first two families are found on plants in their adult and beginning stages, they are parasites during the intermediate stages of growth.

The Meloidae, like the preceding family, have large prominent hind coxae. The claws are cleft or toothed. The vertex is vertical. The antennae are, as a rule, filiform, though sometimes thickened and sometimes reduced. Elytra frequently truncate.

The Rhipiphoridae have the prothorax at base as wide as the elytra, while in the three preceding families it is narrower. The antennae are 11-jointed (10-jointed in certain females), pectinate or flabellate in the males, and frequently serrate in the females. As in Meloidae, the elytra are truncate, sometimes being very small (*Myodites*) and being entirely wanting in *Rhipidius* female. The claws are seldom simple.

The Stylopidae have a very much reduced prothorax, aborted elytra, and reduced flabellate antennae in the males and complete degeneration in the females.

From this brief review we find the place of the three parasitic families lower than the other plant-feeding families. There is of course degeneration in habits. Degeneration of the elytra and reduction in the number of antennal joints are the principal external proofs of degeneration. It is interesting to note the increase of flabellation in the antennae as we approach the last family.

Let us mention here a discrepancy which in our mind should be overruled as being due to degeneracy rather than development. Stylopidae will not run in tables to Heteromera because of the number of tarsal joints. The fossil genus *Triacna* Menge had five-jointed tarsi and two claws. *Stylops* and *Xenos* have four-jointed tarsi and no claws. *Halictophagus* has tarsi three-jointed and *Elenchus* two-jointed (apparently). This is as they have been described.

All three of these families are peculiar because of their parasitic habits. Meloidae and Rhipiphoridae are parasitic on Orthoptera and Hymenoptera, Stylopidae on Hymenoptera and Homoptera.

Among the Meloidae those parasitic on Orthoptera seem to be the highest. *Epicauta, Macrobasis, Mylabis,* and *Henous* in the adults show as a rule entire elytra. In the triungulins they have large, powerful, toothed mandibles and maxillae, and spined legs. They live on the eggs and young of grasshoppers, which they must reach by active burrowing in the ground. They are their own agents in transmission to the host.

*Cantharis, Meloe, Apalus, Sitaris,* and *Hornia* show increased degeneracy in the adults, to the complete loss of the wings and almost entire reduction of the elytra in *Hornia.* In the triungulins also may be noticed increasing degeneracy. These genera and *Horia, Leonidia, Zonitis,* and *Tetraonyx* are known to be parasitic on Hymenoptera. The larvae are conveyed, however, to the host by some other insect—that is, they are passively conveyed. Their feet are specialized for clinging, not digging. Their food is generally honey, hence the mouth-parts are reduced.

The Rhipiphoridae probably belong to a parallel line of descent. The Evaniocerini are the highest in development; their habits are not known. The Rhipiphorini and Myoditini are known to be Hymenopterous parasites. In the latter at least it is known that the transference to the host is passive. The Rhipidiini are very degenerate. The oral organs are atrophied; the elytra short, dehiscent; the wings not folded; the female is larviform, without elytra or wings. *Rhipidius* is a parasite of Blattidae.

The Stylopidae seem very close to *Rhipidius,* having the oral organs atrophied; elytra reduced, wings very simple; the female being larviform, wingless, legless. Like *Rhipidius,* the eyes are very large and prominent.

There is an increase in ventral segments from five in Evaniocerini to eight in *Rhipidius* and sometimes nine in Stylopidae. Stylopidae have lost the tarsal claws in the adult. In the larvae, *Rhipiphorus, Myodites,* and *Xenos* have the feet slender, terminated with a pad or sucker. *Rhipiphorus* has in addi-

tion to the sucker several claws, *Myodites* one claw, and *Xenos* none. All these larvae are Campodeaform.

I am not prepared to enter into an extended discussion of the hypermetamorphic beetles, but shall limit it to those features actually studied or observed during my investigations. The value of the present article should consist mainly in allowing others to compare their views with those herein stated and to come to definite conclusions thereby. Material is at hand for a discussion of the Stylopidae, but it will be held back with the exception of one description of a triunguloid.

For purposes of clearness and conciseness merely descriptions and tables are included herewith, while all biological notes, which refer entirely to *Myodites,* will be found in Part II.

## RHIPIPHORIDAE

*Myodites scaber* Lec. A female, supposedly of this species, was very kindly loaned me by Mr. Warren Knaus. The specimen was taken at McPherson, Kan., in June. The abdomen is red as in *solidaginis.*

The following differences appear between it and *solidaginis.* The pygidium in the former is red, in the latter black. The first joint of the hind tarsus in *scaber* is long, very little thicker than the second; in *solidaginis* it is stout and very thick, and more than twice as long as the second and third joints together. The abdomen of *scaber* is without median spots, while *solidaginis* shows these in every one of over a hundred females examined. The anterior tibiae of *solidaginis* are visibly longer than the tarsi, while in *scaber* they are seemingly shorter than the tarsi.

*Myodites solidaginis* Pierce.[1] In addition to the preceding notes on this species it is important to state that the male averages the same size as the females. In one pair the male was larger than the female.

In the characterization of this species the description of the scutellum is erroneous. It should read: Scutellum triangular, impunctate, hidden by prothorax. Mesothorax very finely densely punctate, pubescent, with well-developed, glabrous, me-

[1]See pl. I, figs. 3, 12.

dian carina. In the description of the anterior and median legs, the word "tibiae" was used where "tarsi" was intended.

In the paper above alluded to a variety from Pine Ridge, Neb., was described. This specimen was taken in July. Aside from the differences already given no more need be said, except that if this is *solidaginis* var. it extends the range over the entire state of Nebraska. Pine Ridge is a high, broken range of foothills, of the Arikaree formation, varying from 4,300 to 5,000 feet, bordering on the barren Little Bad Lands in Sioux county at the extreme northwest corner of the state.

Lincoln is in a comparatively flat country, on the other hand, with an altitude from 1,100 to 1,200 feet. To the north and west of the city lie extensive salt basins in the valley of Salt creek. Concerning these salt basins, Prof. Barbour says:[1] "The area of salt land soil is too restricted to be mentioned, being confined to Salt creek and other salt marshes near Lincoln."

*Myodites solidaginis* is also found at West Point, Neb. This latter place has no salt land or alkaline earth, but does present sandy flats in the vicinities near which *Myodites* is taken.

At Lincoln *Myodites* is only taken in the vicinity of the salt basins. In the latter part of August, from the 23d to the 27th, it is difficult to find a *Solidago* plant without at least one beetle feeding on its flowers.

*Solidago missouriensis, S. canadensis,* and *S. rigida* are the common species, and each in its season is visited.

It is worthy to note the abundance of this particular species in this locality as compared with the supposed scarcity of other species of the genus *Myodites* in other parts. Reasons will be suggested for this abundance in another place in this article.

A close examination of the buds of goldenrod at which *Myodites* has been seen always results in finding one or more young of this beetle. I shall use the term "triunguloid" because of the similarity to the triungulins. "Triungulin" would be a misnomer for this larva and also for the *Stylops* larva.

The triunguloid is a light brown hexapod averaging about .82 mm. in length and .21 mm. in breadth, broadest toward the apex

[1] *Neb. Geol. Surv.*, I, 222.

of the metathorax, tapering to the apex. Head trapezoidal, length and breadth almost equal, and but little narrower than metathorax; antennae with three joints and a terminal filament, not as long as the head; labrum produced, entirely covering mandibles, inflexed at sides forming a little ridge below, also bearing on each side in front of the mandibles a row of spines; mandibles simple, short, curved inward; labial palpi short, soft, two-jointed with base covered by mandibles. Legs well-armed with spines; coxae hollowed out for the reception of the femora. Tarsus apparently three-jointed with a long claw, almost entirely concealed by a large, transparent, fleshy, elliptical sucker which is double its length. Last ventral segment constructed to serve as a clasper or sucker.

For the comparison of *Myodites* triunguloids with those of *Rhipiphorus,* and also of the Meloidae and Stylopidae, the reader is referred to the table at the close of Part I.

*Myodites minimus* n. sp.[1] Male, Belmont, Neb., length 4 mm.

Head depressed, rather coarsely and unevenly punctate, clad with very sparse, whitish pubescence; antennae doubly flabellate, 11-jointed, very finely punctate throughout; vertex between the antennae elevated, rounded, not carinate. Prothorax very unevenly and coarsely punctate; laterally, basally, apically, and discally, glabrous, shining; pubescence very sparse; not carinate and but slightly and very broadly grooved mesially toward apex. Mesothorax with scutellum concealed; apical half coarsely punctate; posterior margin straight. Mesothorax sparsely punctate; postscutellum shining, glabrous, laterally converging, apically truncate. Abdomen coarsely, sparsely, unevenly punctate; finely but sparsely pubescent. Body sparsely punctate, pubescent beneath. Elytra sparsely and shallowy punctate. Posterior tarsi with the first joint not remarkably elongate, as long as second and third joints together, but not equaling the length of fourth, apically thickened, twice as thick as succeeding joints, obliquely truncate, and emarginate behind; second joint over twice as long as third; claws as long as second joint, pectinate. Anterior and median tibiae with the first joint equaling second and third com-

[1]See pl. I, fig. 11.

bined; of the first four joints each is a little longer than the one beyond; fifth equaling second, third, and fourth combined.

Color: Antennae with stalk brown, and pectinations light yellowish-brown, tipped with darker; elytra, anterior and median legs about color of the pectinations of the antennae; posterior legs somewhat darker; head and thorax black; abdomen dark brownish; elytra hyaline, clouded at middle with brown.

**Myodites fasciatus** Say, **brunneus** n. var.[1]

Say's description is so general that the author has not dared to call this a typical *fasciatus*. Before deciding that this is Say's species, it would be necessary to see the type or topotype. The first joint of the hind tarsi is as long as the succeeding three joints, about once and a half as thick, and slightly emarginate and obliquely truncate at tip. The abdomen has a distinct brownish luster. The antennae are brown with black at base; elytra reddish yellow; wings clouded with fuscous; legs light brown, tarsi yellow; prothorax with abbreviated median line; 6 mm.; West Point, Neb., June 20. Specimen in collection of the University of Nebraska.

A specimen at Manhattan, Kan., answers this description also: 5.5 mm.; Riley county, Kan.; Popenoe, May.

Melander and Brues in their paper on the genus *Halictus* record this species as follows:

"Inasmuch as Fabre and others have found the larvae and pupae of a member of this family in the cells of a European species of *Halictus*, it is quite interesting to note the occurrence of *M. fasciatus* about the colonies of the American form. Several specimens were taken while sweeping with the net among the swarming bees as they entered and left their nests."

The following table will aid in the determination of the species of this genus, found in the United States. It is largely remodeled from Le Conte, *Trans. Am. Ent. Soc.*, 1880, vol. VIII, p. 210:

[1] See pl. I, fig. 10.

MYODITES LATR.[1]

1. First joint of hind tarsi elevated, obliquely truncate and emarginate at tip; elytra yellow..... 2
   First joint of hind tarsi long, but slightly thicker, not obliquely truncate ..... 8
2. Female abdomen black, male abdomen black..... 3
   Female abdomen yellow or red, male abdomen ———; or female abdomen ———; male abdomen dark brown or black ..... 4
3. First joint of hind tarsi stout, not more than one-half longer than second; prothorax sparsely punctured, smooth each side in front; 6 mm.; N. Y. *luteipennis* Lec.
   First joint of hind tarsi long, somewhat thicker than the second; prothorax sparsely punctured behind, nearly smooth in front; 5 mm.; Nev.....*nevadicus* Lec.
4. Prothorax smooth on disc ..... 5
   Prothorax densely punctulate ..... 7
5. First joint of hind tarsi stout and thick, not more than one-half longer than the second; vertex sparsely punctured, obtusely rounded ..... 6
   First joint of hind tarsi long, thicker than the second, and more than twice as long; vertex sparsely punctured, not carinate; female abdomen yellow; 7.5 mm.; Md. .....*semiflavus* Lec.
6. Honey yellow; prothorax with sides, median line and base black; prothorax smooth; male unknown; female abdomen yellow; 7.3 mm.; Col.....*popenoi* Lec.
   Black; prothorax smooth on disc, coarsely punctured at base, apex, and sides; abdomen with dark brown luster; female unknown; 4 mm.; Belmont, Neb... .....*minimus* n. sp.
7. Female abdomen red (according to the specimen owned by Knaus, but yellow according to Le Conte); pygidium red; first joint of hind tarsi very long, very little thicker than the second; prothorax and vertex

[1]See pl. I, figs. 10, 11, 12.

densely punctate, the latter carinate; 8 mm.; Indian Ter., Kan., June ..... *scaber* Lec.

Female abdomen red; pygidium black; male abdomen black; first joint of hind tarsi stout and very thick, and more than twice as long as second and third joints together; prothorax and vertex densely punctate; male antennae honey yellow; 7.9 mm.; July to September, *Solidago;* Lincoln, Neb., West Point, Neb.; *Epinomia triangulifera* Vachal host..... ..... *solidaginis* Pierce

Male abdomen black, antennae orange, Pine Ridge, Neb., July ..... *solidaginis* Pierce var.

8. Elytra shining yellow, or black only at base; head and prothorax densely punctate ..... 9

Elytra alutaceous, more or less blackish or piceous..... 11

9. Elytra entirely yellow; hind tarsi with the first joint as long as the others united, scarcely thicker; 5 mm.; Cal. ..... *californicus* Lec.

Elytra black at base ..... 10

10. Body black; 6 mm.; Pa., Ill., Mo., *Chloralictus pruinosus* Rob. host ..... *fasciatus* Say.

Female abdomen dark brown; first joint as long as succeeding three joints, about once and a half as thick, and slightly emarginate and obliquely truncate at tip; 6 mm.; West Point, Neb..... ..... *fasciatus* Say var., *brunneus* n. var.

11. Hind tibiae slightly compressed..... 12

Hind tibiae strongly compressed; black, with small testaceous elytral spot; 6 mm.; Fla.; *Augochlora pura* Say host ..... male *schwarzi* Lec.

12. Vertex strongly elevated and compressed; 6.5 mm.; N. Y. (*zeschii* Lec.)..... female *schwarzi* Lec.

Vertex feebly elevated ..... 13

13. Pectus and abdomen densely punctured; 5 mm.; Ill., N. Y. ..... *walshii* Lec.

Pectus and abdomen more strongly, less densely punctured; 2.5–3 mm.; Can., N. Y., D. C. . *stylopides* Newm.

(*Myodites flavicornis* Say and *americanus* Guér. are not placed in this table because of too general descriptions.)

**Rhipiphorus acutipennis** n. sp.[1]

Described from one male Lincoln, Neb., W. D. Pierce, and from six females, July, Pine Ridge, Neb.; July 16, 1902, July 28, 1902 (two), Carns, Neb., W. D. Pierce; July, 1897, July 23, 1895, Grand Rapids, Mich., R. H. Wolcott. One of each sex in the author's collection; females in the collection of the University of Nebraska.

Length 7.5 mm.–9.5 mm.

See accompanying plate for structure of the prosternum and legs.

Male.—Body entirely black, elytra yellow with apex black. Vertex slightly concave in front, above; upper edge acute; much elevated, very shiny and sparsely punctured. Antennae ochraceous. Thorax convex, slightly concave on each side of middle at apex; posterior angles not produced; medianly angulate, hardly produced, with apex emarginate, and with semicircular lobe elevated just before apex, deeply concave behind; posterior lateral angles and median lobe tinged with rosy color. Elytra continuous for very short distance at base, rapidly narrowing and very acute at tips. Mandibles flattened at base, slightly concave with a rosy tinge; acute at tips, furrowed below. Epistoma long, apically rounded, slightly truncate. Anterior coxae separated in their entire length by a slender prolongation of the prosternum. Second joint of posterior tarsi flattened above, equaling and slightly longer than the third. Spurs of legs rufous, claws yellowish. Body clad with very fine, sparse pubescence.

Female.—Flagellum of antennae black, scape luteous. Basal third of elytra black. Abdomen telescopic, in nature, last segments often drawn in beyond second segment.

[1] See pl. I, fig. 8.

TABLE OF THE SPECIES OF RHIPIPHORUS OF THE UNITED STATES[1]

(Remodeled from Horn, *Trans. Amer. Ent. Soc.*, 1875, vol. V, p. 121.)

1. Anterior coxae contiguous in their entire extent..... 2
   Anterior coxae separated in nearly their entire length by a slender prolongation of the prosternum..... 7
2. Anterior tarsi of male spinulose beneath, elytra very acute 3
   Anterior tarsi of male with three joints pubescent beneath 4
3. Basal lobe of thorax with a strong elevation; second joint of hind tarsi not flattened above.....*flavipennis* Lec.
   Basal lobe of thorax transversely notched at tip; second joint of hind tarsi flattened above....*dimidiatus* Fabr.
4. Second joint of hind tarsi shorter than third and flat above 5
   Second joint of hind tarsi longer than third, subcylindrical; lobe of thorax neither carinate nor notched... ..... *cruentus* Germ.
5. Thoracic lobe with obtuse elevation and a deep fovea on each side .....*bifoveatus* Horn
   Thoracic lobe not elevated; surface regularly convex.... 6
6. Metasternum very densely punctulate, punctures closer together than their own diameter...*octomaculatus* Gerst.
   Metasternum more shining, moderately punctured, punctures distant at least their own diameter..... ..... *pectinatus* Fabr.
7. Vertex scarcely elevated, obtuse, and nearly impunctate.. 8
   Vertex much elevated, acute, sparsely punctured. Second joint of hind tarsi flattened above, equaling and slightly longer than the third; epistoma long, apically rounded, slightly truncate.....*acutipennis* n. sp.
8. Second joint of hind tarsi longer than half the third and not flattened above; epistoma oval.....*lincaris* Lec.
   Second joint of hind tarsi shorter than half the third and flattened above; epistoma truncate.....*limbatus* Fabr.

[1] See pl. I, figs. 8, 9.

## STYLOPIDAE[1]

This family of beetles has always presented difficulties to entomologists and probably will for some time to come. On account of their peculiarities a large amount of literature has been written about them. But from all this literature a very small proportion of facts can be obtained, the remainder being expressions of doubt, or surmises which prove incorrect. If a student were to apply himself to the task and make careful collections he ought to have no difficulty in procuring a large amount of material. The editor of the *Entomological News* in a note, October, 1903, states that from two nests of *Polistes texanus* Cress. from Pecos, Texas, one hundred and forty wasps emerged and thirty-four were stylopized by *Xenos* sp. "Most of the *Xenos* appeared to be females, and only four males were secured. Many of the wasps had a number of parasites on them."

Mr. Hubbard in the *Can. Ent.*, 1892, pp. 257–61, states that he found *Polistes americanus* Fabr. from Florida very commonly stylopized by *Xenos* sp. Mr. Hubbard found that the males were numerous, that they emerged early in the morning, lived but fifteen or twenty minutes, and that the *Polistes* crushed them to pulp as soon as they fell to the ground, dead. This accounts for the scarcity of males in collections. Mr. Hubbard suggests that if the cage were provided with a false floor of wire netting through which the dead *Xenos* could fall, perhaps more specimens could be procured.

Since most of the literature on the subject is available, the author will merely give the bibliography and confine his remarks mainly to observations made upon the material at hand through the aid of the works listed.

### THE GENERA OF STYLOPIDAE

Antennae with third joint lobed or flabellate..... 1

1. Antennae with four joints, fourth simple; tarsi four-jointed .....*Xenos* Rossi (*Pseudoxenos* Saund., *Paraxenos* Saund., *Hylechthrus* Saund.)

[1] See pl. I, figs. 1, 2, 4, 5, 6, 7, 13; pl. II, figs. 3, 4.

Antennae with more than four joints..... 2
2. Joints following third simple..... 3
Joints following third, not all simple..... 4
3. Antennae five-jointed, last two elongate; tarsi apparently only two-jointed .....*Elenchus* Curtis
Antennae six-jointed, last three not very much longer than third; tarsi four-jointed.....*Stylops* Kirby
4. Antennae seven-jointed, fourth joint flabellate; tarsi five-jointed with two claws.....(fossil) *Triacna* Menge
Antennae seven-jointed, fourth, fifth, and sixth joints flabellate; tarsi three-jointed.....*Halictophagus* Dale

(*Myrmecolax,* parasitic on ants, and *Colacina* Westw., parasitic on Homoptera, the author can not locate in default of descriptions.)

Genus *Xenos;* type *X. vesparum* Rossi; August; Europe and America.

Genus *Stylops;* type *S. melittae* Kirby; March 15, May 15; Europe and America.

Genus *Elenchus;* type *E. tenuicornis* Kirby; June–August; England, Mauritius.

Genus *Halictophagus;* type *H. curtisii* Dale; August 15; England.

Genus *Triacna;* type *T. tertiaria* Menge; fossil in amber.

Genus *Colacina;* type *C. insidiator* Westw.; Sarawak.

Genus *Xenos.*

The genus *Xenos* is supposed to be found exclusively on wasps, while *Stylops* is supposed to occur in bees. Hence when a species of *Xenos* is taken from a bee it is immediately suspected to be a new species.

While collecting bees about nine o'clock A.M. on August 10, 1903, on the garden squash, Mr. J. C. Crawford, Jr., of West Point, Neb., took a species of *Panurginus,* in the body of which were two female *Xenos,* and in his collecting tube, flying frantically about, was found a male *Xenos.* It had probably been in copula with one of the females when taken.

**Xenos pulvinipes,** n. sp.[1]

MALE.—Length 2 mm.; color, very dark brown with light yellowish legs.

Antennae four-jointed; first and second joints externally obliquely truncate, emarginate, for the reception of the following joint, very short; third joint with stem as short as preceding joints but elongated anteriorly into a very long, ribbon-like lamella which twists around the fourth joint; fourth joint surpassing third by length of stem of first three; third and fourth joints very slightly inflated, thickly covered with very fine hairs and very closely provided with large sensory pores. Eyes globular; lenses few, large, and separated by slightly raised, densely pubescent partitions.

The mouth-parts of Stylopidae are not well understood, and the author is not able to give a perfect description because of the fact that the type is mounted with the head turned partially sideways and also because of the difficulty of viewing the object with a high power and obstructed light. Three distinct pairs of mouth appendages are, however, visible. The first is a transparent yellow lancet-shaped appendage, curved slightly at the base, toothed near tip, obliquely truncate and acute at tip. This the author regards as the mandible, but as there is no proof as to its point of attachment, nothing definite can be said. The next pair seem to be the maxillae or maxillary palpi. They are three-jointed, the first and second joints about equal and moderately long, the third very long and broadly flattened. The third pair appear to be merely single-jointed appendages (the base, however, is obscured), and are nearly as long as the third joint of the maxillary palpi. This is probably the labial palpus.

The prothorax is a mere band. The mesothorax is about double the length of the prothorax. The metathorax is composed of the typical parts named by Westwood. Following Westwood's nomenclature, the lumbi of the scutum do not meet in the center and are somewhat elevated, with the interior margin rounded; the praescutum and scutellum are distinctly separated, but together resemble a spindle; the postlumbium is shield-shaped,

[1] See pl. I, fig. 1.

rounded behind, lower than the scutellum, rather concave, medianly longitudinally ridged, closely, finely punctate, yellowish; postscutellum long, narrow, surpassing the femoralia which cover the sides of the body and several abdominal segments. The thorax, with the exception of the postlumbium, is finely pubescent. Elytra short, narrow, apically thickened and rumpled into many ridges, thickly pubescent. Wings large, surpassing abdomen, consisting merely of the primary veins, costa, subcosta, radius, and media from the costal stalk and cubitus and anus from the anal stalk; radius arises from sub-costa; none of the veins are branched. The legs can be illustrated better than described. All have four tarsal joints, and these joints each inserted far before the apex of the preceding and with the apex sucker-like. The coxa of the first two pair seems to be single-jointed, long, while the posterior pair apparently has a rather short coxa and a long trochanter. The femora and tibiae are on all pairs longitudinally obliquely furrowed.

The abdomen is short and is mainly characterized by the peculiar genital apparatus. From the anal opening there projects a tube, which is immediately dilated, then turned and narrowed into a very acute curved process.

Female.[1]—A mere sac with chitinized head and neck. Surface closely reticulately marked. Color flavus, with neck and generalized head-structures darker to very dark brown.

Owing to certain limits on the present article a brief statement of existent structures will be made here and complete drawings will accompany this article, but the detailed discussion of the structures must be published later in a distinct article. Specimens at hand show clearly the existence of several species. Certain characters lead us to believe that *pulvinipes* belongs to an undescribed genus. The head is rhomboidal, narrowed in front and constricted behind the eyes. The eyes are distinct and prominent, not faceted. The nerve cord leading to the eyes is very easily found. The mouth-parts are retracted but distinct. Breathing pores are distinct on each side of the body, on each segment.

[1] See pl. 1, fig. 6.

Certain authors have called that part which protrudes from the body of the host the cephalo-thorax. Owing to the fact that the eyes are located at the posterior end of this structure we must consider it the head, and the constricted neck the thorax. The organs of the head cast aside all doubt as to its identity. Considerable work remains to be done on these structures, and more material is desirable.

**Xenos (?) sp.**[1]

The triunguloid of this species is brown, robust, very small. Length .158 mm.; width at second abdominal segment .063 mm. Head shorter than broad; eyes not prominent, consisting of several little blotches of pigment; antennae very small, not as long as eyes are wide (impossible to magnify high enough to ascertain their character); mandibles short, acuminate, about as long as eyes, immediately in front of eyes, not meeting at middle; other mouth parts too small to recognize distinctly. Legs short, slender, weak, hardly equaling in length the width of the prothorax; tibiae terminated by long, almost invisible acuminate pad, which is strongly convex on the edge and almost equals in length the tibiae. Body enlarging gradually to second abdominal and then narrowing to the last segment, which is squarely truncate and terminated at each side by a short tubercle, bearing a long, stout, acuminate stylet, which equals about six segments of the abdomen. Dorsum armed with many short stout spines at the apical edge of each segment; venter armed with but few spines on each abdominal segment.

Twenty-one hundred and fifty-two of these were actually counted as the offspring of one female. They were extracted from the parent's body, in which large numbers of eggs still undeveloped were also found. The parent was found in *Andrena solidaginis* taken in September at Lincoln.

Two other females of the same species taken from a specimen of *Andrena solidaginis,* dated September 18, 1903, appear to be mere sacs full of larvae, many of which have already worked their way to the head. On the other hand two females taken September 30, 1903, on *Andrena solidaginis* are full of unde-

[1] See pl. I, fig. 13.

veloped eggs. The same remark concerning these females is applicable as the one applied to the female of *Xenos pulvinipes.*

HYPERMETAMORPHIC TRIUNGULOIDS

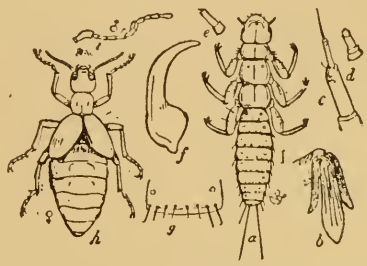
Following is a table of the triunguloids or first larvae of these parasitic beetles, drawn from specimens at hand and published descriptions:[1]

1. Typical triungulins, i. e., with three claws..... 2
   Triunguloids, not having three claws, but possessing a pulvillus or sucker ..... 8
2. Abdomen provided with caudal setae..... 3
   Abdomen provided with caudal spinning apparatus or sucker ..... 7
3. Thoracic joints unequal ..... 4
   Thoracic joints subequal ..... 6
4. Mandibles and maxillae powerful; femora slender; tibiae well armed; tarsal claws slender, spine-like..... 5
5. Mandible toothed; antennae short, last joint bilobed. *Epicauta*
   (*Macrobasis, Mylabris, Henous* also belong here.)
6. Antennae long; mandibles toothless; femora slender; (resembles *Epicauta*)..... *Cantharis*
   Antennae four-jointed with apical bristle; mandibles acute, sinuate, not toothed; femora stout, legs spineless ..... *Meloe*
   (*Apalus* belongs near *Meloc.*)
7. Femora stout; legs spineless; tarsal claws strong, articulating; mandibles toothed; antennae three-jointed with a long apical bristle..... *Sitaris*
8. Tibiae tipped with sucker or pulvillus, and claws..... 9
   Tibiae tipped with a pad or pulvillus, only..... 10
9. Tibiae ending in two or three claws supported by a large transparent pulvillus or sucker of twice their length; each abdominal segment with short lateral spine pointing backwards; last segment terminated by a large double sucker similar to those of the legs ..... *Rhipiphorus paradoxus*

[1] See pl. I, figs. 3, 13, 14, 15; pl. II, figs. 1, 2, 3.

Tibiae bearing an appendage apparently 3-jointed, as a tarsus, and terminated by a curved claw, almost concealed by a large semi-transparent elliptical pulvillus of twice its length; next to last segment laterally armed with long hairs; last ventral terminated by an elliptical sucker.....*Myodites solidaginis*

10. Abdomen squarely truncate behind, not greatly narrowed, armed with two long stylets from posterior corners .....*Stylops, Xenos*



CALIFORNIA MELOE

*a*, Triungulin; *b*, the three triungulin claws; *c*, antenna of same; *d*, maxillary palpus; *e*, labial palpus; *f*, mandible; *g*, an abdominal joint; *h*, imago, female; *i*, antenna of male.—[After Riley from Packard.]

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## Part II.

### THE BIOLOGY OF MYODITES SOLIDAGINIS

*Myodites solidaginis* occurs in great abundance near Lincoln, and hence affords an excellent study in the life history of these parasitic beetles. In discussing this problem the following records and data based on personal observation are placed first. These are followed by the writer's conclusions.

### RECORDS

Following is a complete list of records of the adults of this species to date:

Pine Ridge, Neb., July (*M. solidaginis* var.).

Lincoln, July 29, 1903; *S. missouriensis,* single female; Pierce.

West Point, August 3, 1903; flying, single female; Crawford.

Lincoln, August 17, 1903; *S. canadensis,* 12 females, ovipositing; Pierce.

Lincoln, August 19, 1903; *S. missouriensis, S. canadensis, S. rigida,* 22 females, ovipositing; Pierce, Swenk.

Lincoln, August 21, 1902; *Solidago* all species, many females ovipositing or feeding; Pierce.

Lincoln, August 23, 1903; 1 male in hole of *Epinomia triangulifera* Vachal, pygidium of male in cast of hole, 3 males

hovering around holes, several others seen but not taken; W. D. Pierce, R. G. Pierce.

Lincoln, August 24, 1901; large numbers of females on all species of *Solidago;* Pierce, Cary.

Lincoln, August 25, 1901; a large swarm of males hovering over the holes of a colony of bees of several genera; Crawford. These bees are listed elsewhere in this article (Part III).

Lincoln, August 26, 1901; females on *Solidago;* Pierce.

Lincoln, August 27, 1901; pairs on *Solidago;* Pierce.

Lincoln, August 30, 1903; single female on *Solidago rigida;* Swenk.

*Myodites* is a *Solidago* visitor and parasitic on *Epinomia.* The latter is only a visitor of *Helianthus.* This fact indicates the existence of an intermediate host or carrier; hence there is a necessity for first ascertaining something concerning other *Solidago* insects.

SOLIDAGO INSECTS

A list of bees frequenting the blossoms of *Solidago,* especially *rigida,* has been carefully prepared for the author by Mr. J. C. Crawford of West Point, Neb., and Mr. M. H. Swenk of the State University. This list is large and by itself can give little aid. Since *Myodites* appears with *Solidago* and disappears with it, we may safely say that some one of these bees is probably either a permanent or temporary host.

The following is the list of the bees taken on *Solidago rigida* at Lincoln and West Point, the two known homes of *Myodites solidaginis,* by Mr. Crawford and Mr. Swenk.

Bombidae (Bumble Bees—colonial).

*Bombus americanorum* Fabr. West Point, September 18, Crawford.

*B. pennsylvanicus* DeGeer (*Bombias auricoma* Rob.). West Point, September 18, 1903, September 19, 1903, Crawford.

*B. scutellaris* Cress. (*Bombias*). West Point, September 12, 1903, September 19, 1903, Crawford.

*B. separatus* Cress. (*Bombias*). West Point, September 8, 1903, September 20, 1903, Crawford.

*B. vagans* Sm.(?). West Point, September 12, 1903, Crawford.

Psithyridae (False Bumble Bees—parasitic).

*Psithyrus variabilis* Cress. West Point, September 8, 1903, September 21, 1903, Crawford.

Anthophoridae (solitary bees).

*Anthophora* sp.(?). Lincoln, September 4, 1903, Swenk.

*Melissodes agilis* Cress. Lincoln, September 18, 1903, Bruner.

*Melissodes* sp. West Point, Crawford.

Nomadidae (Cuckoo Bees—parasitic).

*Triepeolus concavus* Cress. (*Epeolus*). West Point, September 18, 1903, Crawford.

*Triepeolus helianthi* Rob. West Point, September 12, 1903, Crawford.

*Epeolus scutellaris* Say. Lincoln, September 18, 1903, Bruner.

*Epeolus* sp. Lincoln, August 27, 1902, Swenk.

*Epeolus* sp. West Point, Crawford.

*Nomada* sp. Lincoln, August 27, 1902, Swenk.

*Melanomada grindeliae* Ckll. (*Nomada*). Lincoln, August 27, 1902, Swenk.

Ceratinidae (Small Carpenter Bees).

*Ceratina tejonensis* Cress. (*C. calcarata* Rob.). West Point, September 19, 1903, Crawford.

Megachilidae (Mason, Leaf-cutting, and Potter Bees).

Osmiinae (Mason Bees).

*Ashmeadiella* sp. Lincoln, August 19, 1903, Pierce.

Megachilinae (Leaf-cutting Bees).

*Megachile latimanus* Say. West Point, September 18, 1903, Crawford.

*Megachile* sp. West Point, September 10, 1903, Crawford.

*Megachile* sp. Lincoln, September 4, 1903, Swenk.

Stelidae (Parasitic Bees).

Coelioxinae.

*Neopasites heliopsis* Rob. Lincoln, August 27, 1902, Swenk.

*Neopasites illinoiensis* Rob. West Point, September 6, 1900, September 12, 1900, Crawford.

*Coelioxys* sp. West Point, September 10, 1901, Crawford.

Panurgidae.

*Halictoides marginatus* Cress. West Point, September 12, 1903, Crawford; Lincoln, September 18, 1903, Bruner, Pierce; August 24, 1902, Crawford.

*Cockerellia albipennis* Cress. (*Perdita*). West Point, September 18, 1903, Crawford.

*Perdita affinis* Cress. Lincoln, August 30, September 4, 1903, Swenk; West Point, September 10, September 11, 1901, Crawford.

*Perdita bruneri* Ckll. West Point, September 10, 1901, September 11, 1901, Crawford.

*Perdita crawfordi* Ckll. Lincoln, August 30, 1902, September 4, 1903, Swenk.

*Panurginus nebraskensis* Crfd. Lincoln, August 24, 1902, Crawford; West Point, September 12, 1901, Crawford.

*Panurginus* sp. Lincoln, September 18, 1903, Bruner.

*Panurginus* spp. Lincoln, September 18, 1903, Pierce; August 30, September 4, 1902, Swenk.

*Calliopsis coloradensis* Cress. West Point, September 12, 1900, September 12, 1901, August 30, 1903, Crawford.

Andrenidae (Acute-tongued Burrowing Bees).

Andreninae.

*Epinomia triangulifera* Vachal (*Nomia persimilis* Ckll). West Point, September 10, 1901, Crawford.

*Andrena helianthi* Rob. West Point, September 12, 1903, Crawford.

*Andrena nubecula* Sm. West Point, September 12, 1903, Crawford; Lincoln, September 18, 1903, Bruner, Pierce.

*Andrena pulchella* Rob. West Point, September 10, 1901, September 8, 1903, September 12, 1903, Crawford; Lincoln, August 24, 1902, Crawford.

*Andrena solidaginis* Rob. Lincoln, August 30, 1902, September 4, 1903, Swenk, September 18, 1903, Bruner.

*Andrena albovirgata* Ckll. West Point, September 8, 1903, September 20, 1903, Crawford.

*Andrena truncata* Vier. West Point, September, Crawford.

Halictinae.

*Augochlora humeralis* Patton. West Point, September 19, 1903, Crawford.

*Agapostemon texanus* Cress. Lincoln, September 18, 1903, Pierce.

*Agapostemon viridulus* Fabr. Lincoln, September 18, 1903, Bruner; West Point, September 19, 1903, September 20, 1903, Crawford.

*Halictus fasciatus* Nyl. Lincoln, September 18, 1903, Bruner.

*Halictus ligatus* Say. Lincoln, September 18, 1903, Bruner.

*Halictus* sp. West Point, Crawford.

Sphecodinae.

*Sphecodes* sp. West Point, Crawford.

Colletidae (Obtuse-tongued Burrowing Bees).

*Colletes armatus* Patton. Lincoln, September 4, 1903, Swenk.

*Colletes americanus* Cress. West Point, Crawford.

*Colletes willistoni* Rob. Lincoln, September 18, 1903, Pierce.

Prosopidae (Obtuse-tongued Carpenter Bees).

*Prosopis bakeri* Ckll. Lincoln, September 18, 1903, Pierce; West Point, September, Crawford; Nebraska City, Carriker.

The principal beetles found on *Solidago* are the following:

1. *Chauliognathus pennsylvanicus* Lec.
2. *Nemognatha immaculata* Say.
3. *Nemognatha sparsa* Lec.
4. *Zonitis bilineata* Say.
5. *Epicauta pennsylvanica* DeG.
6. *Myodites solidaginis* Pierce.

TRIUNGULOID CARRIERS

An examination of all the insects included in the above lists disclosed the fact that several of them, perhaps all, at various times become temporary hosts or carriers of the *Myodites* triunguloids. Following are the results of the investigation:

A lot of twenty-two *Solidago* bees taken by Mr. Swenk on August 8 was first examined. Not one showed signs of triunguloids.

Under the date of August 19, 1903, *Ashmeadiella* was found to bear a triunguloid. (*Ashmeadiella* is a mason bee living in stumps, etc.)

Under date of August 27, 1902, twenty-six bees were examined, of which ten bore larvae. Four were taken on *Melanomada grindeliae.* This bee is a parasite on ground-dwelling bees and will be considered later. Four were taken on *Neopasites helianthopsis;* this bee is also a parasite on ground-dwelling bees. One was taken on *Cockerellia,* a ground-dwelling bee. Nine were on *Epeolus,* another parasite of ground-dwelling bees. One was on *Cerceris,* a predaceous wasp; four on *Halictoides* sp., and one on *Andrena solidaginis,* both of which are ground-dwelling bees.

On examining the collection of adults of *Myodites* itself, better results were obtained, which indicate that it is probably the principal carrier. Twenty-seven males were examined without evidence of the larvae, and out of ninety-two females examined only five bore larvae. Of these, three bore one apiece and were dated August 17, 1903, August 19, 1903, August 21, 1902. One collected August 24, 1901, held two; one collected August 26, 1901, held five.

Having found triunguloids on bees of certain dates, the period at which they might be found elsewhere was indicated. Examinations of the buds of *Solidago* were made at various times. On August 17 and 19, 1903, small quantities of *Solidago* clusters were gathered, and from these twenty-two good specimens of the triunguloid were found. On September 19, 1903, two larvae were taken on goldenrod, one dead, the other alive. On August 21, 1903, several holes of *Epinomia* were dug out, and from the

cells of these, fifteen larvae were collected, all of them considerably shortened and broader than those taken from the flowers.

A list of the dwellers in the *Epinomia* community will be found in Part III.

Additional data concerning the host consist in the finding of males in swarms at the holes on August 23, 1903, and August 25, 1901, and in the finding on the former date portions of the males in the casts of the holes and about the holes, where they had been caught by tiger beetles.

## RESULTS AND FINDINGS

The results of these inquiries are embodied below:

I. Oviposition takes place in the spring. All observations indicate this. The eggs are laid in the green buds of the goldenrod. The female probably dies soon afterward.

II. The triunguloid soon hatches and when the bud opens climbs to a prominent place, where it erects itself by the caudal sucker and patiently awaits the advent of a host. It probably takes nourishment first from the *Solidago*. My reasons are:

1. There is a great increase in size between the minute egg and the triunguloids.

2. If vegetable food were not necessary it would be strange for the adult to lay its eggs on a plant which the host does not visit. The egg would either be laid on *Helianthus* (no *Myodites* was ever taken from *Helianthus*), or the female would lay them in the vicinity of or in the holes of the hosts.

III. The triunguloid attaches itself to any host whatever which is provided with hairs, and in fact shows no preference to any particular portion of the host's body.

IV. Many triunguloids perish. The bees, *Ashmeadiella*, never approach the holes. The probability is that many such cases would be found by close study. One larva was found dead on goldenrod probably due to inability to cling to a host.

V. Vast numbers of larvae reach *Epinomia* holes. Eight of the nine found on bees were on visitors or residents of the *Epinomia* community. A much greater number were found on *Myodites* females. These females undoubtedly hibernate in the

*Epinomia* holes. The largest number of larvae taken from any one kind of location were in the cells of the *Epinomia* holes.

VI. The Rhipiphoridae are supposed to undergo that process of hypermetamorphosis which is found typically in the Meloidae. Following I give a brief outline of this type of transformation:

The eggs are laid in various localities according to the species. The first larva is a triungulin, and is called the instar or campodeoid larva. The behavior of the triungulin diverges along two lines. Members of one group love the dark, and immediately after birth commence to burrow. These are parasitic on Orthoptera. The other group love the light, and they immediately find their way to some flower if not there already. These are mainly parasitic on Hymenoptera and must be carried to the nests of their hosts. Hence they are well developed for clinging to a hair or leg or wing. In the nest they live on the eggs, pollen, honey, or larvae. This parasitic life causes a degeneration of form and after the first moult the larva has the form of a Carabid larva, and is hence called the carabidoid stage of the second larva. The next two moults each shows more degenerate forms, which are called respectively the scarabaeidoid stage and the ultimate stage of the second larva. In these stages the larvae are active. The next moult gives the pseudopupa or coarctate larva, which is semiquiescent. This is generally the stage of hibernation. In the spring the third larva, bearing the same shape as the pseudopupa but being more active, appears. This in a short time moults again into the normal pupal stage.

Dr. T. A. Chapman says that *Rhipiphorus paradoxus* has only three larval stages, in the first of which, after reaching the wasp hole, it lives within the body of its larval host; in the second of which it emerges from the body and clings to the exterior, sucking the body juices, and remaining in this position during the third stage, until fully developed, when it leaves the bee hole and burrows off to the side in order to escape the effects of the rotting host, and transforms into a pupa.

It will probably be difficult to trace these stages of *Myodites* because of its being found two feet underground.

VII. In early August the hibernating females come out and oviposit in great numbers.

VIII. About the 21st of August the transforming generations commence to mature. In a few days they are very active, visiting the flowers for nourishment. During this period fertilization takes place.

IX. During the first part of August there are three generations of *Myodites*—the fertilizing adults, which are ovipositing, their offspring, and the alternating brood which is in the holes, about ready to emerge.

X. Certain reasons for the abundance of *Myodites* seem very plausible.

1. The host is in its prime in this locality. *Epinomia triangulifera* occurs at West Point, Neb., Lincoln, Neb., western Kansas, and New Mexico. In Nebraska it is most numerous at Lincoln. Its only parasite of much importance is *Myodites*, and its greatest enemy is *Cicindela*. *Helianthus* is in abundance, as are also good breeding places. These breeding places are free from cultivation or any artificial disturbances, being subject only to floods. Abundance of host provides for the abundance of parasites.

2. The food plant is not distant from the holes. The insects are only found on *Solidago* in the vicinity of the holes.

3. No enemies except *Cicindela* have been noted. The only apparent dangers to the triunguloids are miscarriage, that is, attachment to insects which will not conduct them to the holes, and complete lack of carriers (this is not likely).

4. All data seem to point to the carrying of the triunguloids by their own species to the holes of their hosts. The carrier is merely an inquiline, while the triunguloid is a parasite. Since *Myodites* is the most numerous *Solidago* insect, the probability is that a large proportion of the triunguloids therefore reach their proper destination.

## Part III

### EPINOMIA

*Epinomia triangulifera* Vachal is a large black bee, recorded only from New Mexico, western Kansas, and Lincoln, Neb. As already stated in the preceding text, it lives colonially on the salt basins of Lincoln. Ten large communities[1] of these bees are known to the author, all within one square mile.

The region is alkaline, but is generally covered with many wild flowers and grasses. Three railways traverse this area, one of them having two branches. Oak creek and Salt creek approach each other quite closely, and between them are at least seven or eight ponds filled by the spring overflows of the two creeks. The ponds are really due to excavations made in building the railroad embankments. The country being low and subject to many overflows, the railroads have found it necessary to raise their tracks about ten feet. Where these excavations have been made are found the bee colonies. Plants are absent, the ground is hard, not under cultivation, and only occasionally bothered by sheep or cattle grazing from the packing houses. Each community is bounded by an elevation of ground about a foot or so high in which are the nests of numerous insects.

Although the author's work hitherto at these colonies has been of secondary importance, it will henceforth be taken up as thoroughly as possible. For several years one or two of these colonies have been known, and during the past summer several others have been found. A study of a single colony will suffice to explain the conditions. As already stated, the only adverse conditions are those brought about by nature. These conditions, however, are very numerous and will appear throughout the discussion.

The first community studied was several hundred feet long and not more than ten feet wide, on an elevation of a foot or so

[1] The term community is here applied to such gatherings, as exhibited by *Epinomia*, in which in a certain limited region are myriads of individual homes, possessed often by very different species. Usually some species predominates and that species gives the name to the community. Several colonial societies might exist in the midst of a community.

above the surrounding ground. On a sunny day in summer, from late July to early September, the air is full of busy buzzing bees and many other insects. The *Epinomia* holes are 7 mm. in diameter at the entrance and are usually surrounded with a little embankment of tiny particles of earth. The holes are usually not more than four or five inches apart, so that in general appearance the community resembles a great expanse of ant-hills. Between the *Epinomia* holes are numerous other holes varying in sizes down to 1 mm. and even less. The appearance and disappearance of certain large holes soon denotes the presence of *Cicindela* larvae, and generally little observation is required to find one or more *Epinomiae* or other insects frantically struggling on the ground in their attempts to free themselves from *Cicindela.* The beetles are represented mainly by *Cicindela fulgida* Say, both the red and the undescribed melanistic forms, and *C. togata* Laf., although *C. punctulata* Fab. is also found. Certain larger holes are those of *Ammophila pictipennis* Walsh. This wasp has been observed dragging large caterpillars to its hole with great industry. It is not very numerous, there being not more than four or five located within the precincts of the bee community, as a general rule.

Although he has examined carefully the contents of a large number of holes in his search for *Myodites,* the author has not made any complete casts. In several cases he has had to do the work alone and has been limited in time. The communities are some distance from the city, and time has prevented leaving the casts long enough to become well hardened. The holes require a large amount of plaster and considerable time is consumed in pouring it. In the future a more careful study of these holes will be made. For this it will be necessary to devise some means for the escape of the air bubbles which have made the work more difficult. Professor Smith in his *Notes on Digger Bees* has very well outlined the details for careful work of this kind, and his plans will probably be adopted.

The holes generally enter the ground perpendicularly, although sometimes at a slight incline. They take a very nearly perpendicular course throughout, sometimes not varying more than an

inch or so from it. The depth varies from fifteen to twenty-two inches or even more. The diameter of the hole is invariable throughout except for the slight irregularities necessarily due to mandibular action. The holes are not enlarged at the bottom, but are evenly and very regularly rounded. Side chambers are found below twelve inches, varying from abandoned galleries of one-quarter inch to an inch and a half. These chambers are generally horizontal and are of the same diameter exactly as the main hole. Occasionally the hole will branch out on its downward path and have two main passages. That smaller holes enter these is very noticeable. Some of these holes are hardly larger than a pin in diameter and reach the main hole by downward, horizontal, or upward directions. They undoubtedly belong to some parasites not yet observed. In many cases roots were found to have entered the holes near the bottom and coiled themselves to form a neat nest in which the bee had deposited pollen masses.

The contents of one certain cell has occasioned a great deal of discussion among those consulted. Not varying whatever in size or shape, it was found to contain at its bottom a very compact mass of skeletal remains of the small sunflower snout-beetle, probably *Smicronyx fulvus,* or a nearly related species. Consider that the hole is not enlarged as is customary among wasps; that these were found at least a foot and a half below ground; that sunflower does not exist within a large radius from the holes; that the beetle and also *Epinomia* are typical *Helianthus* insects; that the only wasps found at the holes besides *Ammophila* are too small to carry the beetle; that the tiger beetle does not customarily visit the sunflower for its prey; that the beetles would not come of their own accord in such number to a single hole; that the only insect at the holes which might be suspected are tiger beetles, bees, and wasps. The author does not attempt to explain. Mr. Titus writes as follows: "I have never found a beetle in any [nest] which I have examined. *Cerceris* spp. do store food in the nests of some bees and *Sphex* sp. will store grasshoppers in nests of spider and *Melissodes obliqua.* They sometimes have to enlarge the holes. The same

with other Fossores. *Cerceris* sp. might easily have stored in *Epinomia* nests. I have found *Osmia* nesting in holes and cells of *Melissodes obliqua* the year following their digging by *obliqua*, and the second year the same cells were occupied for the summer by Fossores and by spiders. The third year *obliqua* was again nesting along the same bluff."

The author has not yet noticed this alternation by dwellers in the communities under observation. Since 1900 Mr. Crawford and the author have watched these holes carefully and *Epinomia* has been almost the sole occupant. As for *Cerceris* it has not yet been taken in the vicinity of the holes, nor has any other wasp besides Ammophila outside of the three families Pemphredonidae, Mimesidae, and Crabronidae.

### MEMBERS OF THE EPINOMIA COMMUNITIES

**Epinomia triangulifera** Vachal.

This bee lives on *Helianthus annuus* and its season coincides with that of its food plant. The bees come out late in July or early in August, and by September 19 are all gone. Some time later than that the author visited the holes and found that by scraping away not more than half an inch of the surface the holes were laid bare. This was in early October and the only forms in the holes were the larvae. On August 20, 1903, in digging out holes, the author found the bee in the larval, pupal, and imaginal stages in the holes—in fact there were all gradations from larva to imago. The holes are 7 to 9 mm. in diameter and go straight down about twenty-one inches. Three or four galleries about three-quarters of an inch in length extend outward, horizontally, near the bottom of the hole.

**Myodites solidaginis** Pierce.

This beetle is the most prominent parasite. Its habits are recorded on the preceding pages. Females have never been found at the holes. Males have been caught hovering over the holes on August 23, 1903, and August 25, 1901. On the former date a male was also found in a hole and also the pygidium of another, and from the contents of the cells fifteen triunguloids were collected.

**Ammophila pictipennis** Walsh.

This is a neighbor of *Epinomia,* but so far as known is not an enemy, its food being caterpillars. The holes are considerably larger than *Epinomia* holes.

**Cicindela fulgida** Say.

**Cicindela togata** Laf.

**Cicindela punctulata** Fab.

These beetles are predaceous on almost anything within their reach. They have been taken in the act of catching *Epinomia* and *Myodites.* The melanistic form of *fulgida* is common on the salt basins, but has not been described. Dr. Wolcott expects to describe it in a revision of the list of Nebraska Cicindelidae.

**Panurginus piercei** Cfd.[1]

The holes of this species are about 4 mm. in diameter and extend straight downward. Usually a little pile of dirt is thrown up and cemented around the entrance. It is found in but one small community. *Epinomia* is also present, but less numerous. The holes have not been investigated. A single specimen has been taken on *Grindelia squarrosa.*

**Halictus ligatus** Say.

Lincoln, September 8, 1903, one female, Pierce. This specimen was taken from a hole 3½ or 4 mm. in diameter, into which a *Nomada* was seen to enter. This bee visits *Solidago.*

**Halictus tegularis** Rob.

Lincoln, August 28, 1900, one female, Crawford. This specimen was collected on coming from a hole.

**Cockerellia albipennis** Cress.

Lincoln, 1901, Crawford, Pierce. Several specimens of this were seen entering small sized holes in these regions. This bee is recorded from *Solidago.*

**Andrena pulchella** Rob.

Lincoln, 1900, Crawford. Only two or three holes of this *Solidago* bee were found.

[1] J. C. Crawford, *Can. Ent.*, December, 1903, p. 335.

The four preceding species are not colonial as far as observed, but seem to have their holes scattered sparsely among the holes of the other species. They are not parasitic. *Cockerellia* is recorded as carrying *Myodites* triunguloid.

**Melanomada grindeliae** Ckll.

Lincoln, September 8, 1903, eight females, Pierce; Lincoln, Crawford. This parasitic bee was found mainly hovering around the holes of *Halictus ligatus* and in several cases was seen to enter these holes. It is a very industrious little bee. It also is a triunguloid carrier.

**Neopasites heliopsis** Rob.

Lincoln, September 8, 1903, four females, Pierce. This is another parasitic bee which was taken in considerable numbers especially around the holes of *Halictus ligatus* and *Panurginus piercei*. *Neopasites* is a triunguloid carrier. It is recorded from *Heliopsis, Grindelia,* and *Solidago.*

**Epeolus** spp.

Lincoln, September 8, 1903, Pierce; West Point, Crawford. Several *Epeoli* were taken in the vicinity of the holes, although not seen to enter any hole. *Epeolus* is a triunguloid carrier. This genus is found abundantly on *Solidago* and *Grindelia.*

**Crabro** sp. (Crabronidae)

This very small wasp was found August 17, 1903, August 21, 1903, and September 8, 1903, hovering constantly around the holes of *Epinomia* and *Panurginus.* There were quite a number of them. Peckham and Peckham in *The Solitary Wasps,* chap. IV, record *Crabro* as dwelling in pithy stems and feeding its young with Muscidae. The species under consideration is much smaller but very probably was in search of the minute flies so abundant about the holes.

**Oxybelus** sp.

A single little specimen of this genus was taken on September 8, 1903, and the same observation made as concerning the preceding genus and those following. Peckham and Peckham in chap. VII record *Oxybelus* as dwelling in the ground and storing its nests with flies.

**Diodontus** (?) spp. (Pemphredonidae).

These wasps were also very small. They were taken August 17, 1903, and September 8, 1903. Like *Crabro* they were hovering around the holes.

**Psen** sp. (Mimesidae).

Three small specimens of this genus were also taken hovering around the holes on the same dates as *Crabro*.

**Spogostylum** (**Argyramoeba**) **analis** Say (?) (Bombyliidae).

Flies of this species are very numerous at the holes. They have often been seen to suddenly dart down at a hole, insert the abdomen, and then quickly fly away. Often they made mistakes, alighting at *Cicindela* holes, and it was very noticeable that they made haste to remove themselves, usually escaping before the *Cicindela* larva had reached the top of its hole. This fact would indicate that oviposition must be almost instantaneous. Williston in his *Manual of N. A. Diptera* states that this genus is parasitic on *Pelopaeus, Megachile, Cemonus, Osmia,* and *Calicodoma*. The present species is probably an *Epinomia* parasite, to judge from its great numbers.

**Mutilla** sp. (*sens latum*).

A small female of the *simillima* group of Fox (*Trans. Am. Ent. Soc.,* XXV, 226) was found on September 7, 1903, crawling around among the holes. It is undoubtedly a parasite on some of the bees dwelling here. It is 4½ mm. long. Head large, slightly wider than thorax, eyes hemispherical, faceted. Antennae with all joints short, scape equaling first three joints of flagellum; first and second flagellar joints subequal, hardly as long as broad; third and fourth subequal, not twice as long as first or second; mandibles evidently not toothed, but broadly sulcate beneath. Thorax one and one-half times longer than broad, sides parallel, narrowed behind middle slightly. First abdominal apically sessile; abdominal segments after first apically fringed with yellowish pubescence; pygidium longitudinally striate, with pygidial area. Reddish brown; pubescence sparse, whitish; abdominal segments after second, black, immaculate; eyes, mandibles, apical half of antennae and legs externally also

black. Punctuation large, distinct, and round on head, confluent on thorax, distinct and slightly longitudinal on abdomen. This species comes nearest *simillima* Smith in the Fox table. The species runs in Ashmead's *Superfamily Vespoidea* to the subfamily Mutillinae. It probably belongs in the tribe Photopsidini running to the genus *Photopsis* Blake. It has points in common with the genus *Timulla* Ashmead in Mutillini, but it differs as to antennal joints.

## SUMMARY

That we may better hold in mind the results of the investigations, a summary of the main points is herewith given:

1. Certain ground-dwelling insects, as *Epinomia,* are often found to dwell in individual homes, but very close to one another. Other species of insects are also found to dwell amongst these holes in holes of their own. Such a colony (*sens latum*) we call a "community."

2. These various insects may or may not have any relations with their neighbors. Some are peaceable (*Panurginus, Halictus*), some are predaceous (*Cicindela, Ammophila*).

3. Parasites are found to live upon and in the holes of these insects (*Myodites* upon *Epinomia,* mites in *Epinomia* holes).

4. Parasites are found to live the entire cycles of their lives within the bodies of certain ground-dwelling bees (Stylopids upon *Andrena, Panurginus, Halictus*).

5. The parasites often reach the holes of the hosts in a very peculiar manner (*Myodites* carried by its own species).

6. Where it is possible to oviposit in the hole of the host it is found that a parasite (*Myodites*) may find it necessary to have vegetable food first, and that the eggs are laid in plants (*Solidago*), which the host (*Epinomia*) never visits (*Epinomia* visits the common sunflower, *Helianthus annuus*).

7. In the case of *Myodites solidaginis* it is found that the life cycle is two years, and that there are two distinct lines of descent alternating in maturing. The interesting item that *Myodites* is a principal carrier of the young of its species and that it is probably the agent of transportation to the holes is of importance. It is very likely that *Myodites* hibernates in the *Epinomia* holes.

8. In the case of the Stylopidae the fact that the female lives throughout life in the body of its host has and always will call forth much interest. The question of fertilization is an unsettled problem. The ovoviviparous habit of Stylopidae is striking. It is probably the only instance of such a habit among the insects undergoing complete metamorphosis.

9. The increasing degeneracy of the Heteromerous beetles as their food increases in animal nature and as the parasitism develops; the occurrence of hypermetamorphosis among the parasitic forms; the loss by Stylopidae of the principal Heteromerous characters, rendering their determination difficult and their systematic position doubtful, are all points worthy of note.

10. The hypermetamorphosis exhibited by these beetles is peculiar to themselves. The first larva is a highly specialized larva resembling certain adult Thysanura (*Campodea*). The second and successive stages are more degenerate, becoming apodous. The pupa is normal.

11. While all of the above points are by no means new to science, the evidence at hand has emphasized them—hence the mention.

## EXPLANATION OF PLATES

### Plate I. Figures Drawn by W. Dwight Pierce

Fig. 1. *Xenos pulvinipes* Pierce. Type male. West Point, Neb., August 10, 1903, from *Panurginus* sp.; *b*, antenna; *c*, left elytron; *d*, posterior leg; *e*, anterior leg; *f*, median leg; *g*, genitalia from side view.

Fig. 2. Diagrammatic forms of stylopid antennae. *a*, *Stylops;* *b*, *Xenos;* *c*, *Elenchus;* *d*, *Halictophagus.*

Fig. 3. *Myodites solidaginis* Pierce. *a*, Triunguloid, ventral view; *b*, posterior leg; *c*, coxa from above by optical section; *d*, pulvillus and tarsal claw from side view; *e*, pulvillus from above; *f*, mouth-parts, ventral. Actual size, 82 mm.

Fig. 4. Female stylopid from *Andrena solidaginis;* August 30, 1903, Lincoln. *b*, head, ventral; *c*, female from *Andrena solidaginis*, September, Lincoln; head showing young within.

Fig. 5. *Xenos* sp. from *Polistes* sp.; Hat creek valley, Nebraska, August. *a*, Pupa of male; *b*, presumably larval head of male; *c*, head of female.

Fig. 6. *Xenos pulvinipes.* Type female, West Point, Neb., August 10, 1903, from *Panurginus* sp.; head.

Fig. 7. Stylopid female from *Andrena illinoiensis*, April, Lincoln.

Fig. 8. *Rhipiphorus acutipennis.* *a*, Ventral view of thorax.

Note—Fig. 8*b* and Fig. 9 are missing.

Fig. 10. *Myodites fasciatus brunneus*, posterior tarsus.

Fig. 11. *Myodites minimus*, posterior tarsus.

Fig. 12. *Myodites solidaginis*, posterior tarsus; *b*, claw.

Fig. 13. Stylopid triunguloid extracted from parent, taken in body of *Andrena solidaginis;* Lincoln, September. Actual size .158 mm.

Fig. 14. Meloid triungulin from *Andrena* sp., Pullman, Washington. Actual size, excluding stylets, 1.35 mm.

Fig. 15. Meloid triungulin from *Andrena* sp. nov.; Lewiston, Idaho (five specimens taken from one bee). Actual size, excluding stylets, .55 mm.

### Plate II. Figures from Packard

Fig. 1. Oil beetle. *a*, First larva; *b*, second larva; *c*, third larva; *d*, pupa.

Fig 2. *Sitaris.* *a*, Triungulin; *g*, anal spinnerets of same; *b*, second larva; *c*, true pupa; *d*, female adult; *e*, pseudopupa; *f*, third larva.—[After Mayet from Packard.]

Fig. 3. Triunguloid of *Stylops childreni.*

Fig. 4. *Stylops childreni*, male. *a*, Abdomen of *Andrena* with female *Stylops* (*b*).

PLATE I

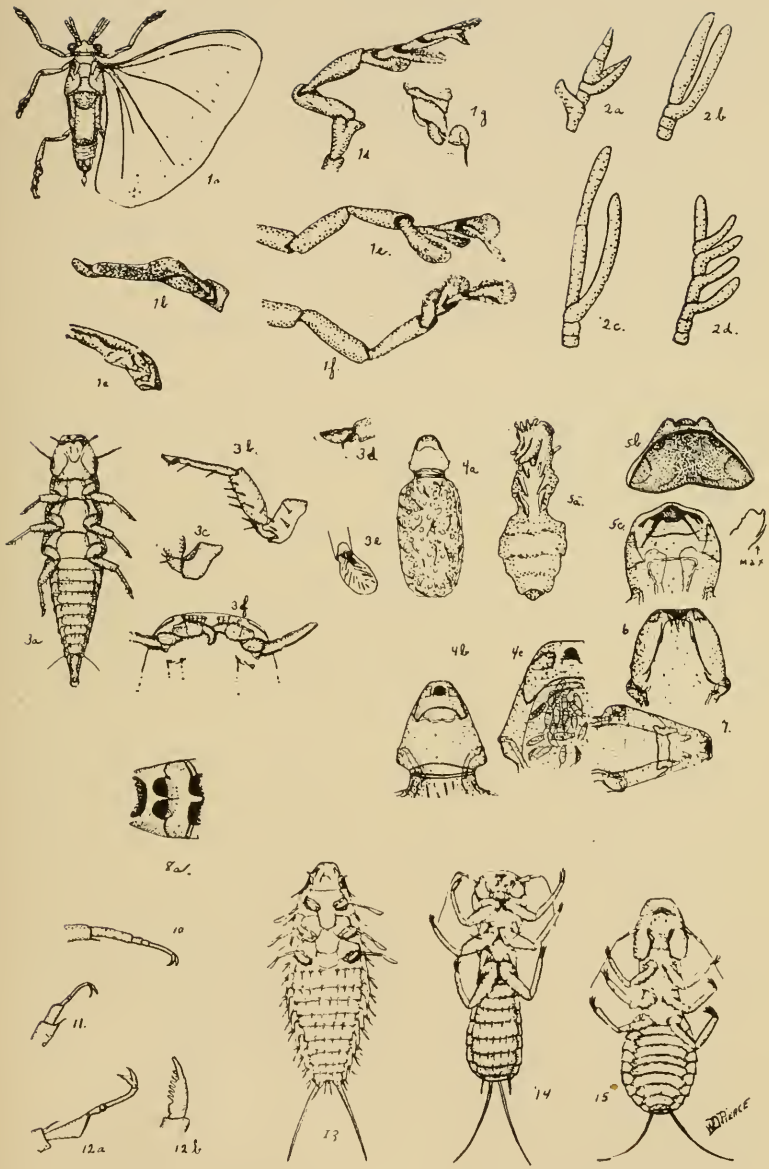
1a
1g
1d
1e
1b
1c
1f
2a
2b
2c
2d
3a
3b
3d
3c
3e
3f
4a
4b
4c
5a
5b
5c
max
6
7
8a
10
11
12a
12b
13
14
15
W.D. Pierce

PLATE II

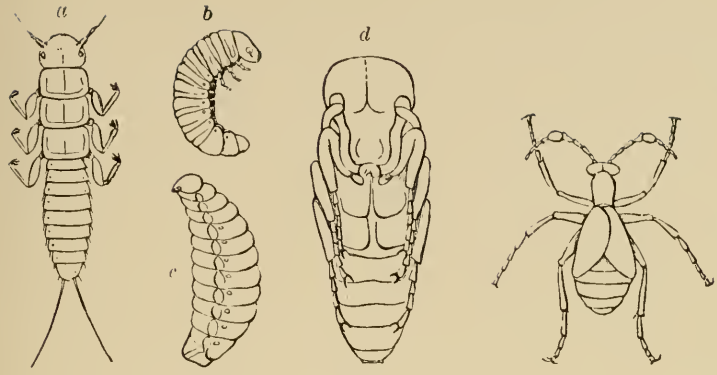


*Fig. 1*

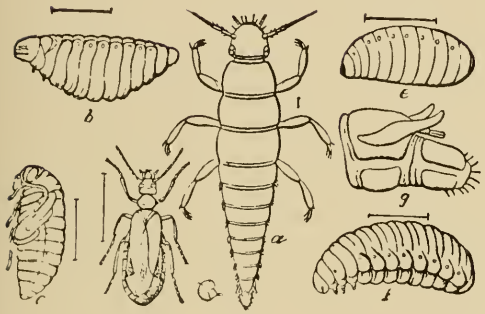


*Fig. 2*

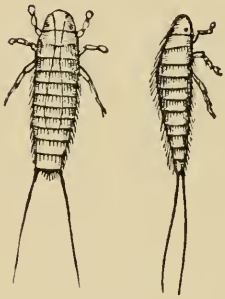

*Fig. 3*

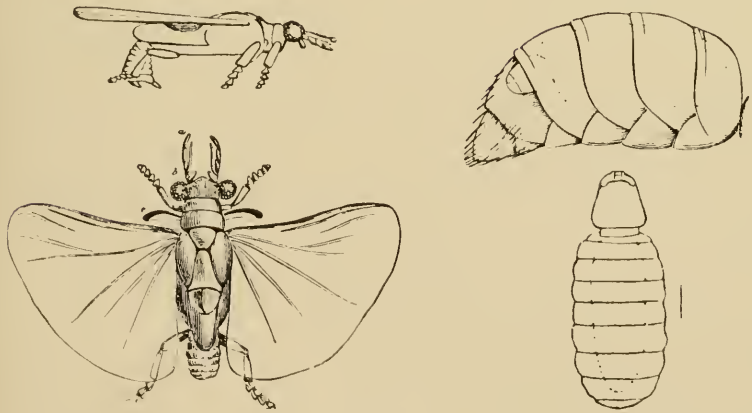

*Fig. 4*

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# University Studies

Vol. IV *JULY, 1904* No. 3


## I.—*Variation in the Hooks of the Dog-Tapeworms,* Taenia serrata *and* Taenia serialis

### Part I


BY EARLE C. STEVENSON


This paper was submitted as a thesis for a master's degree in the department of zoology at the University of Nebraska, Lincoln, (*Studies from the Zoological Laboratory, under the Direction of Henry B. Ward, No. 59*) in May, 1903. Since then Dr. Carl C. Engberg, instructor in biometrics in the University of Nebraska, has been able to work over the derived data and to deduce from them more complete and extended conclusions than would have been possible for one less versed in this field of mathematics. I have accordingly deemed it for the best interests of scientific investigation to withdraw entirely my somewhat incomplete studies on the mathematical side of the question which were contained in the original thesis, and to have the mathematical discussion appear as a whole in the second part of the paper, for which Dr. Engberg accordingly becomes responsible.

#### COLLECTION OF MATERIAL

Under the direction and instruction of Dr. Henry B. Ward, I took up the study of these parasites during the summer of 1901. In cooperation with Mr. B. L. Doane, B. Sc., of the University

of Nebraska, who at that time contemplated a study of these same parasites with regard to other anatomical structures, I began the collection of material in and near the city of Lincoln, Neb.

Stray dogs from the smaller towns about Lincoln, and the dogs taken up by the pound-master in Lincoln, were examined for parasites. All but four of the thirty-five dogs examined were infested with parasites of some sort. About forty specimens of *Taenia serrata*, twenty of *Taenia serialis*, as well as numerous roundworms and hundreds of *Dipylidium caninum* were found in the intestines. Eight dogs carried specimens of *T. serrata* and two contained *T. serialis*.

The dogs were killed with potassium cyanide and examined before becoming cold. Beginning at the stomach, the whole alimentary tract was slit open, and the parasites when found were placed in warm water and washed, then killed in corrosive sublimate and preserved in 70 per cent alcohol.

In classifying the specimens collected, each host was given a serial number, and the portion of the intestine where the worm was attached noted; the parasites from each host were bottled separately and the species determined later.

In preparing the hooks for study, which was a difficult matter because of their minuteness and the necessity of perfect isolation from the tissue of the rostellum, the heads were cut off, then placed in 35 per cent alcohol for a few minutes, and afterward transferred to a drop of glycerine, which was used for a macerating fluid because of its advantage as a mounting medium. The smallness of the hooks, their fragile structure, and firm setting in the tissues caused many of them to be broken in separating them from the tissue; at first about 35 to 50 per cent of the hooks were either lost or broken, but with practice this loss was decreased to less than 25 per cent. A pair of finely pointed needles served as dissecting instruments, and a dissecting microscope gave the necessary magnification for careful isolation of the structures. The hooks being separated from the tissues, a cover-glass was placed over the drop of glycerine containing the hooks, and sealed with balsam, most of the mounts remaining intact one year after preparation.

In the study of the hooks a Leitz compound microscope was used with a No. 2 ocular and No. 7 and No. 8 objectives, magnifying the projected drawing 416.5 and 568 times respectively. By means of the camera lucida, each hook was projected and drawn, care being taken to have the same relative position and adjustment at all times of the tube length, camera lucida, and drawing board. The No. 7 objective was used in examining the hooks of *T. serrata,* and the No. 8 objective for the hooks of *T. serialis.* All measurements were made on the projected drawings, with a scale prepared by projecting a stage micrometer, making the magnification correspond to that of the projected hooks. This method of measurement is more accurate than measuring with an eye-piece scale, as with the latter it is practically impossible to locate definitely constant points on the hooks, since it is necessary to manipulate both the eye-piece scale and the mount in making the different measurements.

The distance between two parallel lines placed one at each extremity of the hook, and perpendicular to a line connecting the two extremities, is taken as the total length of the hook and designated as character *a* (see fig. 9, pl. III). Character *c,* the anterior chord length, is the distance from the point of the prong to the point of tangency on the extremity of the ventral root, of a line drawn from the point of the prong. Character *b,* the posterior chord length, is the distance from the point of tangency on the ventral root to the extremity of the dorsal root. Character *d* is the length of the perpendicular from the anterior chord to the highest point of the curve of the prong.

It is readily apparent from the figure that the anterior and posterior extremities of the hook and the tangency point on the ventral root are the constant points for measurement in all the hooks. It is necessary to select constancy points of this general character because of the variation in the shape and relative position of the different parts of the hook.

The four measurements of the hook are taken for the purpose of correlation or comparison of these characters with regard to their relative deviation from a mean magnitude to be determined. For instance, character *a* is correlated with character *b* and *a*

with *c*. By this method it is determined whether one character *a*, regarded as "subject," varies in an equal or approximate ratio with its relative *b* or *c*. Each hook when measured was numbered and a corresponding number placed opposite the record of magnitudes of that hook, making it possible to compare the drawings of any two hooks whose magnitudes presented any particular deviation in one or more of its characters. The large hooks of each species were considered apart from the small hooks of that species.

In the seriation or classification of data the varying magnitudes of any one character were grouped into classes with a class range of 3 microns; all measurements were made in microns. This minute distinction may seem arbitrary and over-precise at first thought, but when it is noted that 3 microns actual value are represented on the magnified drawing by 1.75 mm. when No. 8 objective was used, and 1.33 mm. when No. 7 objective was used, the practice is seen to be perfectly rational. For the greater magnitudes of the hooks a wider class range could be used, but in considering the smaller character, *d*, a smaller class range is imperative. From these arranged data the mean or abscissa of the center of gravity of the magnitudes of the total number of hooks, and the mean magnitude of the total number of measurements, can be computed. The limits of the magnitude variation of any one character are also established.

With the method of study thus briefly outlined, the development of the hooks should be reviewed, since the question of growth of the hooks influences the significance of the results obtained in this study.

## POSITION AND ATTACHMENT OF THE HOOKS

(Figs. 47, 48, 49, Pl. VI)

In the two species of tapeworms under discussion the hooks are restricted to a circular margin on the very short rostellum, within the region bounded by the four cup-shaped suckers that are located one at each corner of the square head. The rostellum in these parasites is very short and rudimentary (see fig. 47, pl.

VI). The hooks are set into the tissues of the rostellum, each hook resting in a sort of socket. The large hooks are located in the inner row of the double crown, and project above the smaller hooks which are in the outer row. Küchenmeister did not consider that the hooks possessed any movement other than that occurring simultaneously with general motions of the rostellum. According to his view there were no muscle fibers in connection with the radical portion of the hook, therefore there could be no special movement of the hook that would change its posture or position in its socket. Examination of the preserved rostellum, however, shows the presence of numerous muscle fibers, and observation of a number of the preserved heads shows the action of the muscles, since in some cases the hooks are projected with their points directed toward the lateral border of the head, while in other instances the hooks are retracted and the points directed upward. Goeze (1782) speaks of having observed the live worm protract and retract its hooks. The presence of two types of hooks in the same head also may be taken as an argument for a certain individual movement, which assists the parasite in burrowing into the tissues of the alimentary canal.

## FUNCTION OF THE HOOKS

Werner (1782), discussing the hooks of *T. serrata,* suggested the idea that the hooks were sheaths for sucking bladders which could be extruded and retracted, serving the purpose of securing nourishment. This view was occasioned, of course, by an erroneous conception of the structure of the hook and of the true character of the pulpy mass within the cavity of the hook.

Goeze (1782) held somewhat the same opinion as Werner as to the function of the hooks. Steinbuch (1801), however, considered the hooks to be organs of attachment, which, by tearing the tissues of the intestine, also assisted the suckers in the work of securing nourishment.

Wagener (1854) describes the hooks of *Cysticercus pisiformis* as possessing a small opening at the point of the prong, and thought that he had observed pulsations and movements within

the cavity of the hook. From these observations he concluded that the hooks might function as suctorial organs. After examination of a large number of hooks, both of *Cysticercus pisiformis,* and of the adult *Taenia serrata,* however, I have found no such openings in them.

The position of the hooks on the head and the manner in which they are found imbedded in the tissue of the intestine demonstrate that they are essentially organs of attachment.

## LIFE HISTORY OF *T. serrata* AND *T. serialis*

The gravid segments, escaping with the feces, carry the eggs which constitute the source of new infections. The eggs are conveyed in food or water into the stomach of the hare, where the action of the fluids of the stomach destroys the shell, thus releasing the embryo, which bores through the intestinal wall. The onchosphere, according to Küchenmeister (1857), may be either passive or active in its migrations to parts of the body, after penetrating the wall of the alimentary canal. Embryos have been found in the blood by Leuckart, and in such cases would be assisted in movements by the blood current.

The onchosphere at the time of its migration possesses six minute hooks (5 to 7$\mu$ in length) which are used in burrowing through the tissues. These hooks, according to Leuckart, are either lost when the embryo is in the blood or are soon cast off after encystment. The following account of the development of the permanent crown of hooks is taken from Leuckart, Küchenmeister, and Wagener.

The encysted stage in the life history of *T. serrata* is known as *Cysticercus pisiformis,* and of *T. serialis* as *Coenurus serialis.* During the formation of this stage, the adult crown of hooks is developed. Papillae appear on the epithelial coat at the bottom of the flask-shaped cavity which represents the beginning in the embryo of the head of the adult parasite. These papillae become elongated into hollow cones, the walls of which are membranous. These membranous cones, though at first very delicate and fragile, become hard and resistant by the deposit of chitin in successive

layers, and represent what are to be the prongs or sickles of the mature hooks. The cone, which is open at the bottom, is developed to its mature size before formation of the radical portion of the hook, which first appears as a horseshoe-shaped body separate from the prong, but later fusing with it. The hook must be completely formed before the *Cysticercus* is eaten by the dog, or this larva will not develop into the adult *Taenia*. As soon as the cyst arrives in the stomach of the dog, it is ruptured, and the larva, thus released, passes into the intestine, where it attaches itself by means of its hooks to the intestinal wall.

Küchenmeister (1852) maintains that, after entrance into the alimentary canal, the hooks grow both in size and in number; he bases his view on the fact that there is a difference in the number and size of the hooks of the *Cysticercus pisiformis* and those of the adult *Taenia serrata*. He has even worked out a mathematical relation or proportion between the number of hooks of the *Cysticercus* and the adult stage of *Cysticercus fasciolaris*, showing a general law governing the increase in the number of hooks in the adult parasite over the original number in the *Cysticercus*. I may state, however, that a number of *Cysticerci* examined during my work showed a wide variation in the number of hooks in the individual heads.

From this fact it is evident that one is dealing with very irregular data in computing such a relation. Küchenmeister supposed that the mode of increase in the number of hooks was either a development of other secondary hooks between the primary hooks, or that an annual moulting of hooks occurred, two hooks being added in the number developed after each moulting. In thus determining the age of a parasite by means of its hooks, the question arises as to the original number of hooks in each *Cysticercus*, and as this number is known to be so irregular, the theory is seen to be wholly unreliable. No positive evidence of moulting is recorded, though Küchenmeister cites as probable evidence seven cases where tapeworms of a species not given were removed from individuals during the month of March, and bore no hooks, but exhibited traces of having possessed such at some former time. The suggestion followed that if the time of year for moult-

ing could be ascertained, the removal of the parasites would be much easier, as their attachment to the intestinal wall would be at that time much less firm.

Whatever be the cause or causes of the difference in the number and size of the hooks in different individuals from the same and different dogs, the fact that there is a difference in the variation in the size of the hooks on some individual heads amounting to over one-half of the total difference between hooks of the different heads, is proof that a factor other than supposed processes of moulting, or difference in age, must be considered in studying the growth of the hooks.

It is evident that Leuckart regarded the hook as fully developed in the *Cysticercus* stage. Whether or not the hooks grow after entrance of the *Cysticercus* into the alimentary canal of the dog is a question directly influencing the data used in this paper. If a constant factor, such as age, affects the magnitudes of the hooks, and is not considered in measurements taken, the results in averages are unreliable. It is therefore assumed that practically constant normal characters are under consideration.

## DESCRIPTION OF THE HOOKS

*Taenia serrata.*—O. Deffke (1891) gives a fairly typical drawing of the hooks of *Taenia serrata,* but observation will show wide deviations from this figure. This is also true of all the figures I have found in works of different authors. In the small hooks of *Taenia serrata* the angle of the arc and position of the dorsal and ventral roots affects all the magnitudes; some of the small hooks have the point of the prong bent sharply downward, while others have a variation in the angle of the prongs of hooks of the same *a* magnitude.

These peculiarities make a difference in the chord magnitudes *b* and *c*. The ventral root, which is bifid, will have the prongs slanting more forward in some cases than in others, but in all hooks these branches extend laterally, as is seen in Plate II, fig. 8*a*. This lateral projection of parts of the ventral root will cause the hook to tilt either forward or backward when on its side, and

thus account for a very slight amount of the variation in the magnitudes of the chord lengths as measured in the drawing. The branches of the ventral root will be either exactly opposed to each other in position, or one branch will slant forward and the other backward.

This is partly due to the tilting of the hook, though not entirely. In the extreme cases it is merely a matter of judgment as to what is the proper point from which to measure, but usually the anterior branch was used. These two branches are often of unequal length, and in such cases the longer branch was used in measurement. The cleft between the two branches is exceedingly variable in its depth, and may be, in fact usually is, reduced to a mere furrow or shallow depression extending from the base of the root on either side over the end (pl. I, figs. 2, 3, 4). In other hooks the cleft extends into the root fully two-thirds of its length (pl. I, fig. 5).

The general outline of the small hooks also varies from an even and continuous to a rough and broken margin. A deep notch occurs immediately behind the ventral root in some cases and is followed by an abrupt elevation that gradually inclines backwards for a short distance to a level with the general outline of the dorsal root. Usually this notch is absent, though there is always the elevation noted. The end of the dorsal root is usually club-shaped, but is occasionally drawn out to a point (pl. III, figs. 14, 15). The dorsal line of the hook may or may not have an angle at the origin of the blade or prong. The majority of the small hooks present a very even outline for the dorsal root.

### LARGE HOOKS OF *Taenia serrata*

The large hooks of *Taenia serrata* present as irregular an outline as the small ones. The ventral root varies in shape, size, and direction of its slant, but is not bifid. The anterior margin may pass evenly into the lower margin of the blade, but quite frequently there occurs a notch at the base of the root. The posterior margin may also present the same differences as the anterior. Different authors describe the ventral root as heart-

shaped, but it is often pointed or broad and blunt (pl. IV, fig. 33; pl. V, fig. 43). On the lower margin of the dorsal root at its origin usually occurs a more or less abrupt elevation, but frequently this is graduated in its origin and termination. The posterior end of the dorsal root is usually broader than the middle portion, but not infrequently it is narrower. The upper boundary is very rough in outline, there being in some hooks one or more deep notches; and in many cases at the base of the blade is found an abrupt shoulder, marking the point of projection of the blade from the tissues.

In many of the hooks the back margin of the blade just in front of the shoulder is undulate or ridged (pl. IV, figs. 34, 35). The prong of many of the large hooks is sharply bent downward at the extreme point. One peculiar feature noticed is shown in pl. III, fig. 19, where the anterior and posterior extremities of the hook have apparent additions to the original length, though the length with the added parts corresponds to the usual magnitude of the mature hook. This peculiarity, also occurring in some of the small hooks of this species, is presumed to be caused by a greater deposit of chitin on the inner walls of the hook during its growth.

### SMALL HOOKS OF *Taenia serialis*

The hooks of *Taenia serialis* are easily distinguished from those of *Taenia serrata* by means of their lesser magnitude and their characteristic differences in shape and outline. The small hooks are bifid and also present a wide difference in the depth of the cleft between the branches of the ventral root. The body of the hook is more slender and the anterior root much longer than in the small hooks of *Taenia serrata*. The branches of the ventral root vary in their mutual positions as in *Taenia serrata*. Usually the outline of the branches is regular and even, gently rounding at the point, but frequently the root may be broadened and flattened (pl. III, fig. 20). At the base of the root on the posterior side there may occur a deep notch, though more frequently the margin passes in a gradual curve into the lower boundary of the dorsal root, which is usually enlarged near its

end and then tapered sharply to the end; however, the root may continue evenly toward the end and be gently rounded or drawn out to a point (pl. III, figs. 22, 23). Only in rare cases is the upward bend of the end of the dorsal root wanting. The outline of the dorsal root is, as a rule, quite regular, but occasionally presents elevations and depressions at irregular intervals. The upper margin may pass gradually into the back boundary of the blade, but quite frequently a slight angle marks the transition. The blade tapers regularly, but in a few instances is abruptly pointed (pl. III, fig. 20). It is to be noted that the dorsal root varies extensively in length and that the ventral root is often a broad, flat, solid body.

### LARGE HOOKS OF *Taenia serialis*

The large hooks of *Taenia serialis* vary greatly in general form and comparative volume, some being heavier-bodied than others. The ventral root is undivided, its anterior margin slanting forward in a gentle curve to its base, where it then turns abruptly backward for a short space, then passes into the lower boundary of the blade which varies in the angle of the curvature, as in the case of the hooks of *Taenia serrata;* also, it often has the point bent sharply downward. The back margin of the blade passes in an even course to its base, where it makes an angle with the upper boundary of the dorsal root, which has almost invariably in its course a single depression and elevation, though frequently a second depression and elevation are present. The end of the dorsal root is usually rounded, but very often is either blunt or tapering. The lower margin of the dorsal root is uniform in its course, excepting for a slight downward inclination where it meets the posterior boundary of the ventral root. In many of the hooks there are, however, along this margin, depressions and elevations at irregular intervals. The end of the dorsal root may or may not be bent upward or downward from its general direction.

In general the shape and form of the hooks of the two species are similar, but in detail of outline the hooks of *Taenia serialis* are the most variable. The hooks of both species are flattened

laterally, and the pulp-filled cavity of the hook conforms to the oval shape of the body as is shown in cross-section (pl. VI, fig. 50). The number of hooks on each individual head varies in both species. The specimens under my observation gave a numerical range of 34 to 48 for *T. serrata,* and of 30 to 32 for *T. serialis;* the number of small hooks equaled the number of large hooks on each head.

The following table gives the observations of several authors regarding the number and size of the hooks of the two species under discussion:

*Taenia serrata*

| | NO. OF HOOKS | LARGE HOOKS: LENGTH IN $\mu$ | SMALL HOOKS LENGTH IN $\mu$ |
|---|---|---|---|
| Baillet (1866) | 44–46 | 225–256 | 135–162 |
| Baillet (Deffke, 1891) | 34–36 | 230–260 | 140–160 |
| Blanchard R. (1885) | 34–48 | 225–250 | 130–162 |
| Deffke (1891) | 34–38 | 260 | 120 |
| Dujardin (1845) | 48 | 135 (?erroneous) | ..... |
| Krabbe (1866) | 40–42 | 230–240 | 130 |
| Küchenmeister (1852) | 42 | 276 | 191 |
| Küchenmeister (Deffke, 1891) | 34–40 | 230 | 150 |
| [1]Leuckart (Deffke, 1891) | 40–48 | 250 | 140 |
| [1]Leuckart (1879) | 38–48 | ..... | ..... |
| Railliet (1886) | 34–48 | 225–250 | 130–162 |
| Railliet (1893) | 34–48 | 225–250 | 120–160 |
| [2]Stevenson (1904) | 34–48 | 246–294 | 132–177 |
| Zürn (1882) | 38–42 | 220–230 | 140–150 |

*Taenia serialis*

| | NO. OF HOOKS | LARGE HOOKS LENGTH IN $\mu$ | SMALL HOOKS: LENGTH IN $\mu$ |
|---|---|---|---|
| Baillet (1886) | 26–32 | 135–157 | 85–112 |
| [2]Stevenson (1904) | 30–32 | 139–175 | 78–114 |
| Reinitz (1885) | 30 | 139–146 | 101–107 |

[1]I did not succeed in finding Leuckart's original figures quoted by Deffke (1901), but the number of hooks given by Leuckart (1879), does not agree with Deffke's citation.

[2]The present paper.

The measurements given by Reinitz are those of the bladder-worm (*Coenurus serialis*) and not of the adult parasite, and are given, not for direct comparison with the hooks of the adult parasite, but to show that the hooks of the bladder-worms examined are not less in magnitude than are some of the hooks of the adult parasite examined by Baillet. This fact is to be noted in connection with the discussion of the growth and development of the hooks of the species under discussion earlier in this paper.

From the above table it is seen that the range of the number of hooks of the specimens collected at Lincoln corresponds to the average limits given by the writers mentioned. There were examined at Lincoln, Neb., 28 specimens of *T. serrata* and 15 specimens of *T. serialis*. In comparing the relative magnitudes of the hooks of the two species of parasites studied, an interesting coincidence is noted, in that the range of magnitude for character *a* of the large hooks of *T. serialis* is the same as the range of character *a* of the small hooks of *T. serrata*.

Comparison of the results of my measurements of hooks with the measurements made by the observers mentioned shows that the most striking feature of this paper is the excessive magnitude of the hooks of the parasites found at Lincoln, Neb. To account for this difference is a problematic matter; yet it is not at all an extreme suggestion nor improbable circumstance that geographic distribution may account in part for the variation. There is also a possibility of inaccurate computation of magnification of the different microscopes used by different investigators. An example of such an error is found in Deffke's article, where he gives as magnitude of the large hooks of *T. serrata*, 260 $\mu$, and of the small hooks 120 $\mu$, and then gives a drawing magnified 480 times according to the text. The figures of the hooks are not magnified 480 times, else the original hooks, large ones, were only 131 $\mu$ in length, and small ones 70 $\mu$. To have the drawings given consistent with the magnitude of the hook that is given, the drawing would be magnified only about 250 times. The error may well be due to a reduction in size made in connection with the reproduction of the original drawings.

KEY TO CLASSIFICATION OF *T. serrata* AND *T. serialis*

Subfamily *Taeniinae.* Diagnosis. *Taeniidae:* Large species, strobila segmented, with the ripe segments longer than broad. Scolex with a short, rudimentary rostellum armed with a double crown of hooks. In some instances the rostellum is modified into a sucker, whose armament becomes rudimentary and disappears. Genital pores irregularly alternate; usually large numbers of testes in lateral portions of median field; yolk gland, shell gland, and ovary in posterior half of median zone. Uterus with a median stem developing lateral branches, which in the ripe segments entirely obliterate the other genital organs. Egg shell thin and delicate; embryonic shell thick and richly striated. Encysted stage in plant-eating mammals: adult in man and flesh-eating mammals.

Genus *Taenia.* Diagnosis. *Taeniinae:* Same characters as subfamily.

Species *Taenia serrata.* Diagnosis. *Taenia:* Strobila serrated, 60 cm. to 2 m. in length; head from 1.5 to 2.0 mm. in diameter, bearing 4 suckers, one at each corner. Short rostellum armed with a double crown of 34 to 48 hooks: large hooks (inner row), 246 to 294 $\mu$ in length; small hooks (outer row), 132 $\mu$ to 177 $\mu$ in length. Ventral root of small hooks bifid. Uterus stem median, with 8 to 10 richly branched lateral branches. Gravid segments 4.9 mm. long by 4.2 mm. broad anteriorly, posteriorly 4.7 mm. broad, and at opening of genital pore 4.8 mm. broad.[1]

Embryophore ovoid. Genital pore very salient.

SYNONYMY.—*Lumbricus latus* Tyson 1683 (from the dog); *T. canina* Bloch (part.) 1782; *T. canina solium* Werner 1782; *T. canina* Carlisle 1793; *T. serrata* Goeze 1782; *Alyselminthus serratus* Zeder 1800; *Halysis serrata* Zeder 1803 (not *T. serrata* Rosa 1794; not *T. serrata* Röll 1853; not *T. serrata* [from *Cysticercus tenuicollis*] Küchenmeister 1852).

Species *Taenia serialis.* Diagnosis. *Taenia:* Strobila 45 to 72 cm. in length; head globular, 0.85 to 1.3 mm. in diameter.

[1] Dr. Vital (1874) has reported a case of *T. serrata* occurring in man. The specimen was found in company with a specimen of *T. solium* in the intestine of a young girl at the Military hospital at Constantine (Algiers).

Rostellum short, armed with a double crown of 26 to 32 hooks; large hooks (inner row) 139 to 175 $\mu$ in length, small hooks (outer row) 78 to 114 $\mu$ in length. Uterus median with 20 to 25 lateral branches.

Ventral root of small hooks bifid. Gravid segments narrower than those of *T. serrata.* Embryophore ovoid.

Synonymy.—Because of its close resemblance to *T. coenurus, T. serialis* was formerly confused with that species. Experiments with its bladder-worm, *Coenurus serialis,* in the rabbit, by French experimenters, confirmed its distinctness from *T. coenurus,* and it was classed as a distinct species by Baillet in 1863.

For the sake of comparison with *T. serialis,* the diagnosis of *T. coenurus* is given.

Species *T. coenurus.* Diagnosis. *Taenia:* Strobila 40 to 60 cm. in length; head pyriform, 0.8 mm. in diameter. Rostellum short, armed with a double crown of 22 to 32 hooks; small hooks (outer row) 90 to 130 $\mu$ in length; large hooks (inner row) 150 to to 170 $\mu$ long.

Ventral root of small hooks *not bifid.* Gravid segments broader than those of *T. serialis.* Embryophore spherical.

Synonymy.—*T. coenurus* Küchenmeister 1853; *T.* (*Cystotaenia*) *coenurus* Leuckart 1853.

### hooks of *T. serrata* and *T. serialis*

Examination of a large number of these hooks shows a marked variation in different particulars. There is not only a variation in the number of hooks found on the individual heads of the same species, but the hooks of the same and different heads of that species differ from one another in size, general conformation, and mutual relation of parts.

In comparison of the hooks, each species is considered separately. There is such an extreme deviation in the comparative magnitudes of the hooks of *T. serrata* and those of *T. serialis,* that detailed differences need not be noted in distinguishing between the two species. As these hooks approximate very closely in some characteristics the hooks of certain allied cestodes, it is necessary to obtain a definite and exact description of the *T.*

*serrata* and *T. serialis* hooks if they are to be used, as heretofore, as a reliable basis in identifying the species.

It is in relation to this question of determining species by means of the hooks that the practical value of this statistical work exists.

By studying a large number of hooks from several different worms, an average type may be established, and many apparent peculiarities and abnormalities shown to be practically common factors. For instance, the shape and relative position of the ventral root, barb, tooth, or radical portion of the hook, as different writers term it, is determined by observing the prevailing type in a group.

## SUMMARY OF RESULTS OF OBSERVATIONS

1. The average length of the hooks of *Taenia serrata* and *Taenia serialis* found in dogs at Lincoln, Neb., is much in excess of the measurements of hooks of the same parasites observed in other places by different investigators. A comparison of the limits in the table on page 12 will show the divergence.

2. The correlation between characters *a* and *b* in each group of hooks of both species is nearer unity than is the correlation between characters *a* and *c*.

3. The depth of the cleft in the ventral root of the small hooks of both species is usually very slight.

4. While the general form and outline of the hooks of both species is quite variable in detail, yet it is practically always that which is typical of the average hook.

5. The dorsal root of all the hooks of both species is the most variable in length of any part of the hook, and with the exception of a single head of *T. serialis,* character *b* is always greater than character *c*. This exception occurred only in the case of the small hooks of the specimen.

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## EXPLANATION OF PLATES

PLATE I.

Fig. 1. A large hook of *T. serrata*. × 627.

Figs. 2–4. Different views of the same small hook of *T. serialis*, showing the shape of ventral root. × 310.

Fig. 5. Large hook of *T. serialis*. × 488.

PLATE II.

Fig. 6. *a*. Large and small hooks of *T. serrata*. × 199.
*b*. Large and small hooks of *T. serialis*. × 199.
*c*. Large and small hooks of *T. coenurus*. × 199.

Fig. 7. *a*, *b*, *c*, *d*, *e*. Different stages in the development of the hooks of *T. serrata*. (*a*, *b*, *c*, *e*, after Leuckart, 1856; *d*, original drawing.)

Fig. 8. A crown of hooks of *Cysticercus pisiformis*. × 111.
*a*, a small hook showing the lateral projection of prongs of ventral root.

PLATE III.

Figs. 9–19. Large hooks of *T. serialis*, showing the various shapes and outlines. × 242.

Figs. 20–23, Small hooks of *T. serialis*, showing different shapes and outlines. × 242.

PLATE IV.

Figs. 24–31. Small hooks of *T. serrata*, showing different shapes and outlines. × 234.

Figs. 32–35; 43–46. Large hooks of *T. serrata*, showing different shapes and outlines. × 234.

PLATE V.

Figs. 36–41. Small hooks of *T. serrata* superimposed to show the variation in relative position of homologous parts of different hooks having the same magnitude *a*. × 234.

Fig. 42. A small hook of *T. serrata* with prongs of ventral root widely separated. × 234.

PLATE VI.

Fig. 47. Side view of head of *T. serrata*, showing the hooks *in situ*, and the position of the suckers, also the first marks of segmentation of the strobila posterior of the head. × 40.

Fig. 48. Anterior view of the head of *T. serialis*, showing the crown of hooks and the position of the suckers. × 28.

Fig. 49. Same view of head of *T. serrata*, × 28.

Fig. 50. Portion of a section through the rostellum, cutting the hooks transversely. *a*. Cross-section of prong of a hook, cut just in front of the ventral root.

PLATE I

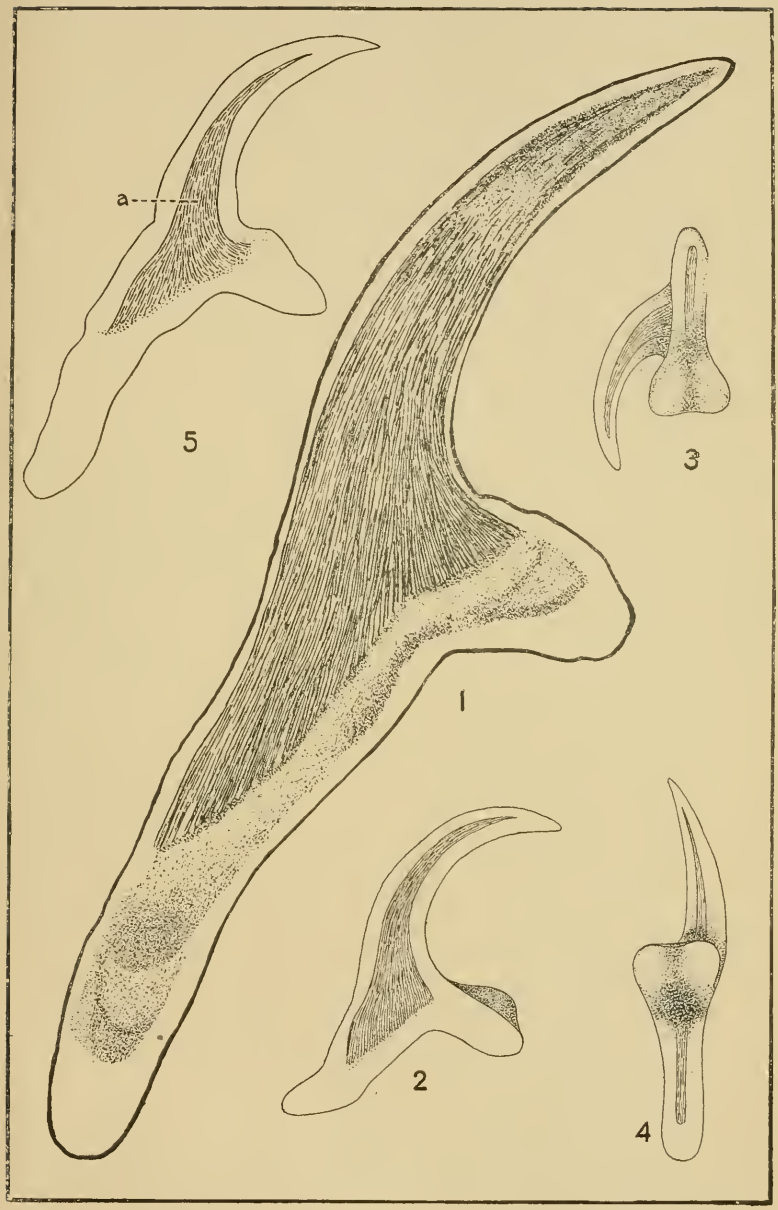


PLATE II

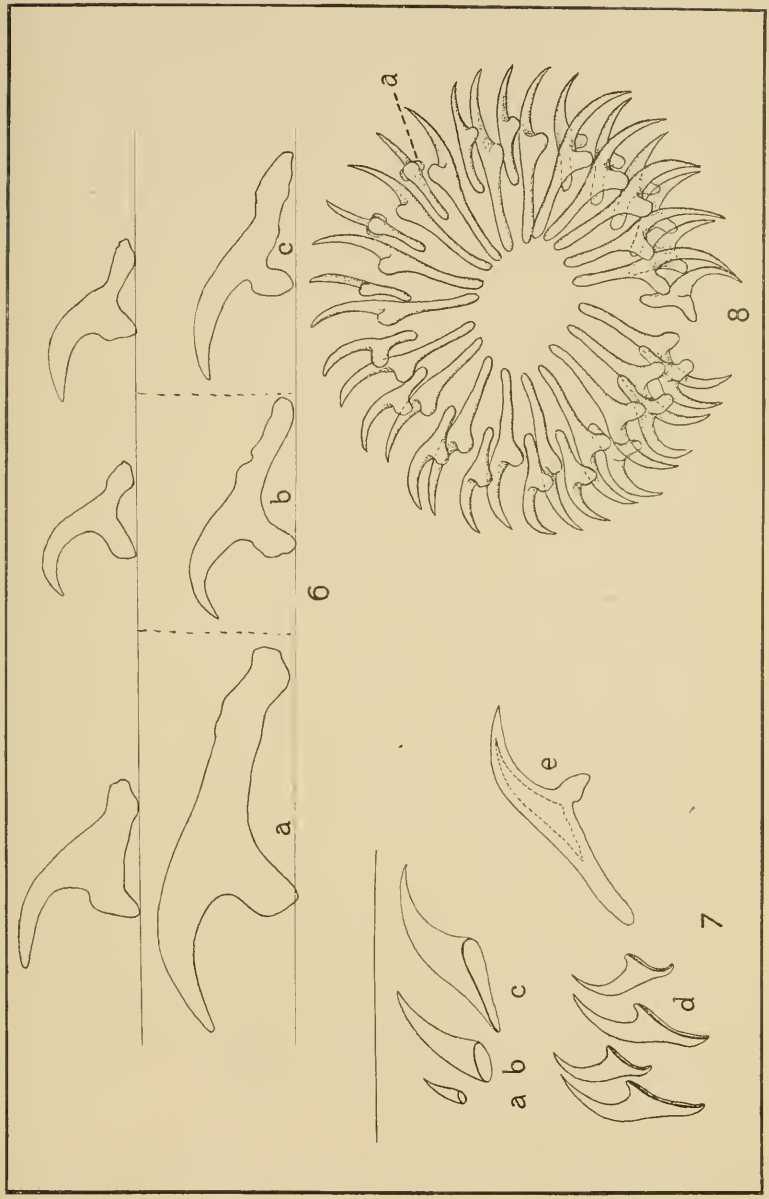


PLATE III

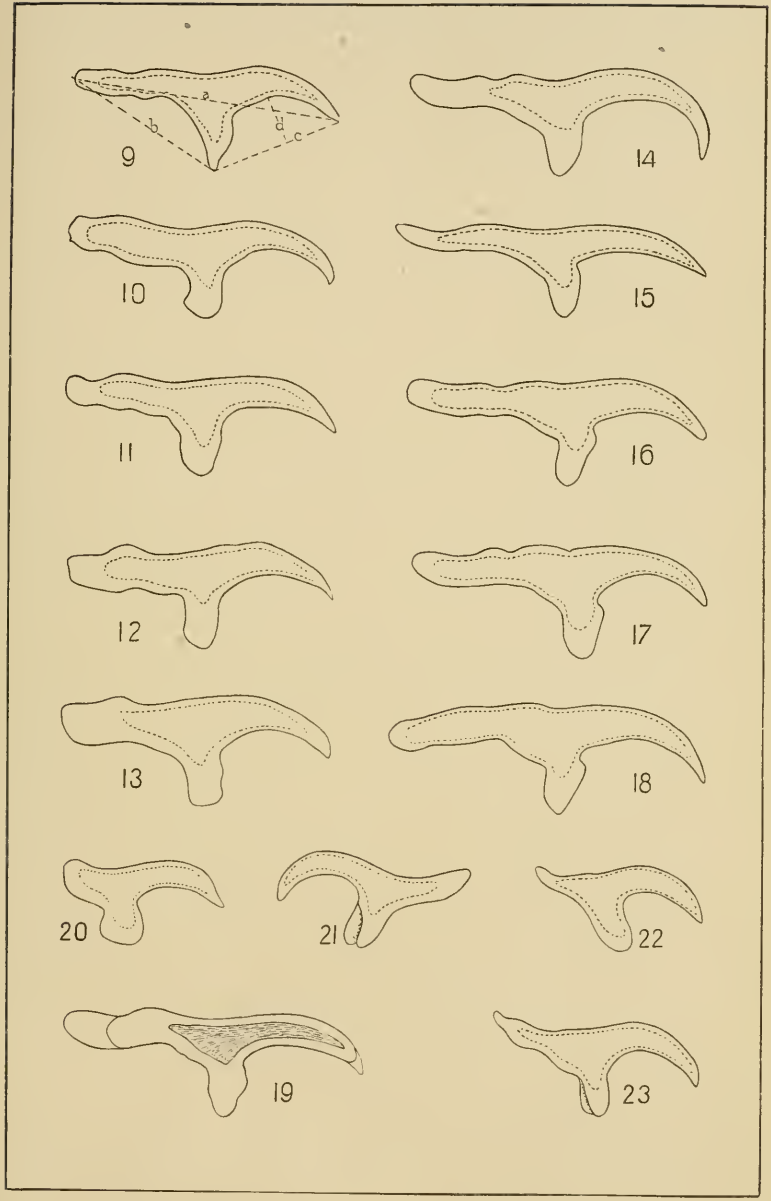


PLATE IV

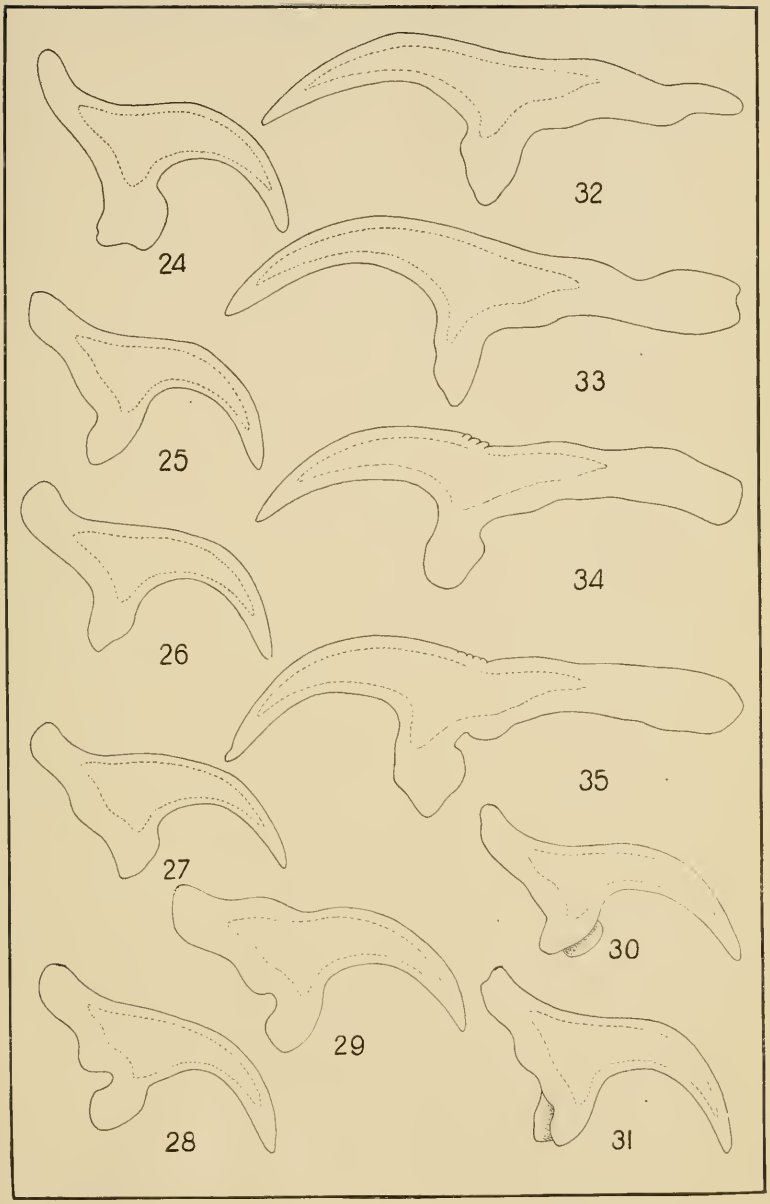
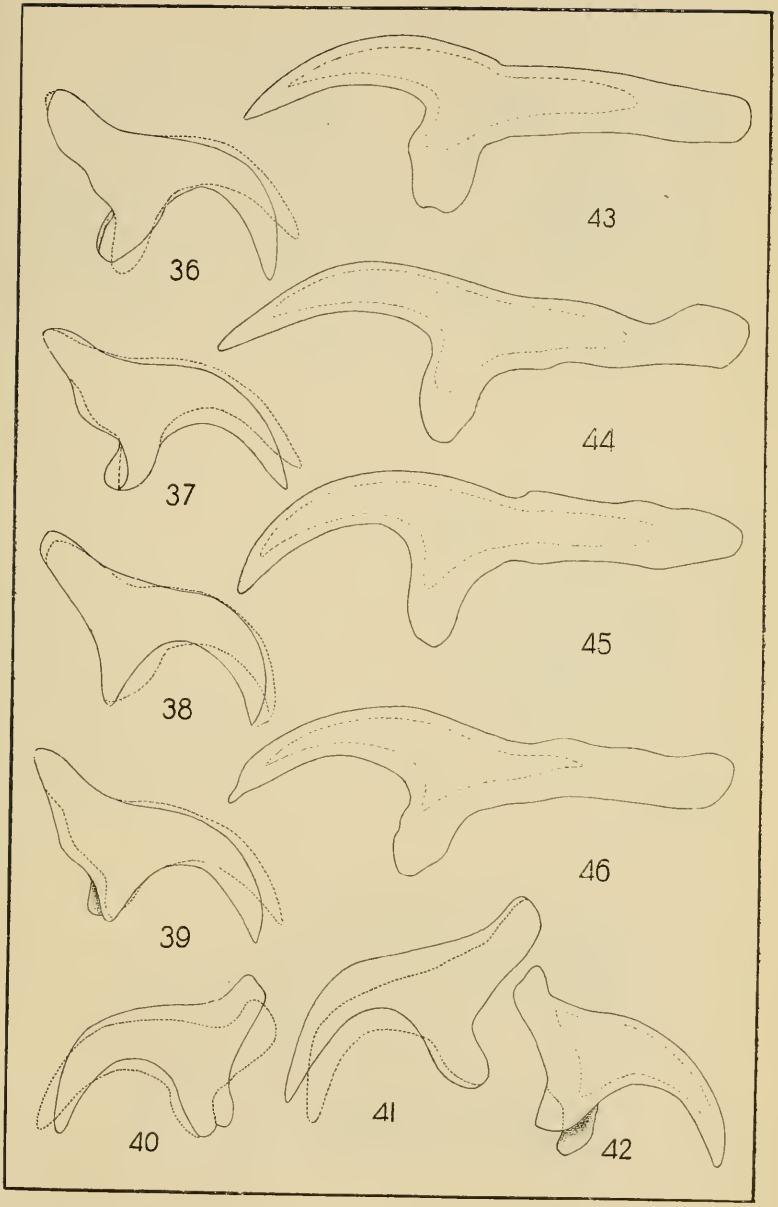
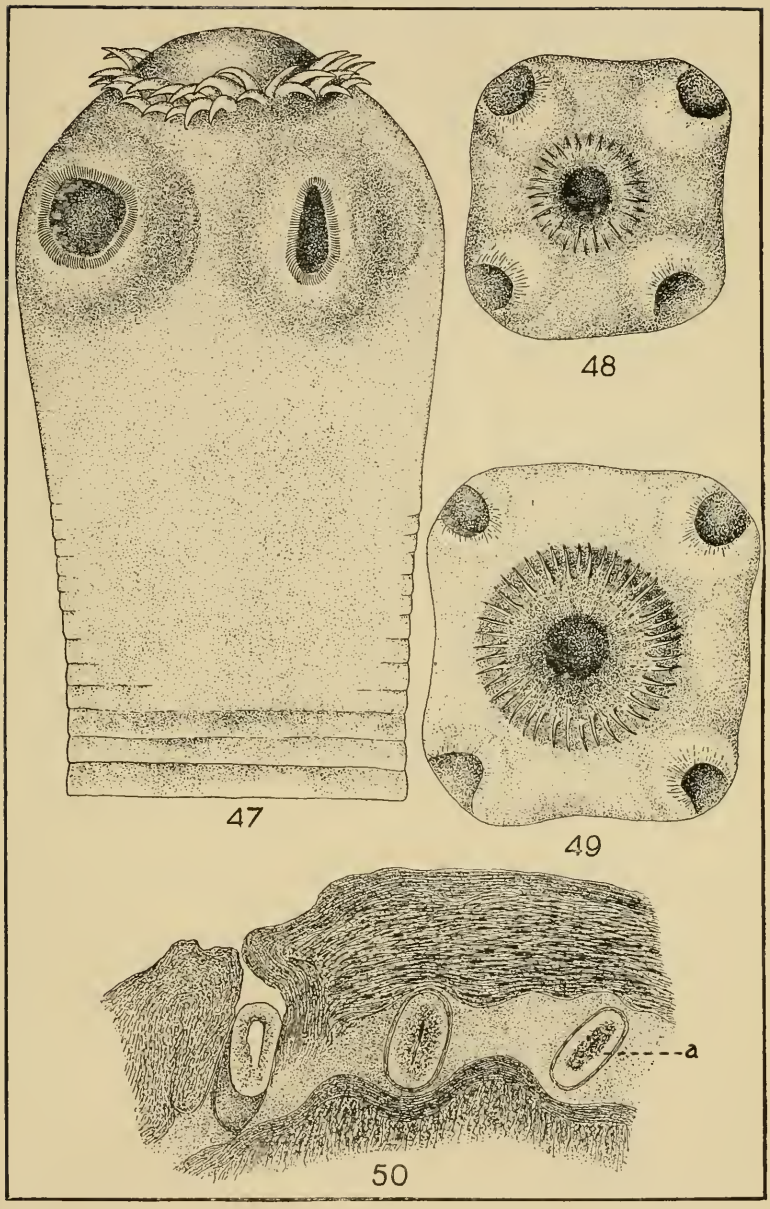


PLATE V



## PLATE VI

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## Part II. Mathematical

BY C. C. ENGBERG

This paper is devoted chiefly to the study of the variability of the various parts of the hooks of the dog-tapeworms, *Taenia serrata* and *T. serialis,* and the correlations of these parts to one another. The data used are those obtained by Mr. E. C. Stevenson, who discusses them from a zoological standpoint in Part I of this joint paper. In these discussions certain mathematical constants and formulae are used, which may be defined here.

1. The Standard Deviation, abbreviated S. D. and symbolized by the Greek letter $\sigma$. It may be proved both mathematically and physically that the measure of variability is that deviation from the mean magnitude whose square is the mean of the squares of the individual deviations. The mathematical statement of this is

$$\sigma = \sqrt{\frac{\Sigma x^2 . f}{n}} =$$

$$\sqrt{\frac{\text{Sum of [(deviation of class from mean)}^2\text{. frequency of class]}}{\text{number of variates.}}}$$

2. The standard deviation gives the absolute variability of the character under consideration, while for purposes of comparison a relative measure is required, as is seen from the fact that the difference of a ton in the weight of two elephants is not relatively so large as a difference of an ounce in the weight of two mice. A good relative measure of the variability is obtained by dividing the standard deviation by the mean ($M$) and multiplying by 100, which gives the coefficient in terms of per cent; that is, the coefficient of variability.

$$V = \frac{\sigma}{M} \cdot 100\,\%$$

3. The coefficient of corre'ation $\rho$. Correlated variability is such a relation between the magnitudes of two characters that any abmodality of the one is accompanied by a corresponding abmodality of the other. This coefficient varies evidently between the limits $\pm$ 1. If two characters are perfectly correlated the value of $\rho$ is evidently 1, while 0 indicates no correlation. A negative value of $\rho$ shows that while one character increases the other decreases. The mathematical formula is

$$\rho = \frac{\Sigma f xy}{n \sigma_x \sigma_y} = \frac{\text{Sum of products of (deviation of subj. class} \times \text{deviation of each assoc. rel. class} \times \text{number of cases in both)}}{\text{total no. of individ.} \times \text{S. D. of subj.} \times \text{S. D. of rel.}}$$

In this paper Duncker's short method of computing the correlation is used. He puts the above formula into the following form:

$$\rho = \frac{\Sigma_4^1(fXY) - \Sigma_1(fX) - \Sigma_1(fY) + \Sigma_1(f) - \Sigma_2(fY) - \Sigma_3(fX) - n\xi\eta}{n \sigma_x \sigma_y}$$

where $X$ and $Y$ are the integral parts of the deviations from the means of subject and relative respectively, $\xi$ and $\eta$ are the complements of the fractional parts of these means, $f$ stands for the number of cases, and the numbers indicating the summation refer to the quadrants as shown in the correlation table.

## EXPLANATION OF THE TABLES

These tables were compiled by Mr. E. C. Stevenson from the data obtained by him.

Table I gives the measurements of the hooks of 28 worms of the species *Taenia serrata.* The measurements of the large and small hooks of the same head are given on the same line, thus making possible a comparison of the dimensions of the two kinds of hooks.

Table II gives the same measurements similarly arranged for the hooks of 15 worms of the species *Taenia serialis.*

Table III is a correlation table for characters *a* and *b* of the small hooks of *Taenia serrata.* It is divided into 4 quadrants by lines drawn through the zero points, i. e., the means. The column

headed $X$ and the row headed $Y$ give respectively the integral parts of the deviations from the means of $a$ and $b$. The Roman numeral found in each quadrant indicates its number. The remaining tables are correlation tables for the characters $a$, $b$, $c$, and $d$.

After these introductory remarks we may at once enumerate the results obtained as farther explanation of the methods used seems unnecessary.

COEFFICIENTS OF CORRELATION

| | | |
|---|---|---|
| *Taenia serrata*..... | Large hooks..... | Correlation $a : b =$ .62<br>" $a : c =$ .52<br>" $c : d =$ .38<br>" $b : c = -.21$ |
| | Small hooks..... | Correlation $a : b =$ .70<br>" $a : c =$ .49<br>" $c : d =$ .13<br>" $b : c = -.09$ |
| *Taenia serialis*..... | Large hooks..... | Correlation $a : b =$ .71<br>" $a : c =$ .59<br>" $c : d =$ .32<br>" $b : c =$ .26 |
| | Small hooks..... | Correlation $a : b =$ .76<br>" $a : c =$ .34<br>" $c : d =$ .06<br>" $b : c =$ .11 |

We gather from this table that, while the correlations of $a$ to $b$ and $a$ to $c$ are mostly quite large, the correlations of $b$ to $c$ are very small, and in two cases even negative. Or, in other words, while a large $a$ implies a large $b$ and also a large $c$, a large $b$ may imply a small $c$. This apparent paradox is readily explained when we consider that we are dealing with correlation "in the long run," and that an infinite number of variations may arise affecting characters $b$ and $c$ which belong to the same character $a$, in such a way as totally to negate any expected correlation between $b$ and $c$.

From the fact that the posterior chord length follows more closely the total length of the hook than does the anterior chord length, we see that, as the hook gets larger, the increase is more in the root than in the claw. This, it seems to me, has an important bearing on the question of the functions of the hooks. The fact that the firmness of the fastenings of the hooks increases relatively faster than the length of the claw indicates that the hook is intended for rough work, such as grasping—thus enabling the worm to attach itself to the walls of the intestines—tearing and lacerating.

We also see that characters *c* and *d* are very slightly correlated, which means that the shape and size of the claw are nearly independent of each other.

MEAN, STANDARD DEVIATION, AND COEF. OF VARIABILITY

| | | CHARACTER | MEAN. | S. D. | V. IN % |
|---|---|---|---|---|---|
| *Taenia serrata.* | Large hooks.. | *a* | 266.37 | 9.62 | 3.61 |
| | | *b* | 173.69 | 8.09 | 4.66 |
| | | *c* | 107.68 | 7.94 | 7.37 |
| | | *d* | 49.19 | 3.30 | 6.71 |
| | Small hooks.. | *a* | 151.99 | 7.59 | 4.99 |
| | | *b* | 94 90 | 6.80 | 7.17 |
| | | *c* | 85.39 | 5.64 | 6.60 |
| | | *d* | 40.20 | 3.41 | 8.48 |
| *Taenia serialis.* | Large hooks.. | *a* | 153.93 | 7.07 | 4.59 |
| | | *b* | 97.75 | 5.37 | 5.50 |
| | | *c* | 73.19 | 3.41 | 4.66 |
| | | *d* | 30.23 | 1.88 | 6.22 |
| | Small hooks.. | *a* | 99.91 | 7.04 | 7.05 |
| | | *b* | 64.94 | 6.72 | 10.35 |
| | | *c* | 52.93 | 3.88 | 7.33 |
| | | *d* | 26.67 | 2.48 | 9.30 |

These figures clearly disprove the assertions made by biologists that character *a* is the most variable part of the hook. Its standard deviation is, to be sure, the largest of the standard deviations, but its coefficient of variation, i. e., its relative variability,

is the smallest in every case, and it is hence the least variable of all the parts. Next in order comes *c* in three out of the four cases, while *d* appears to be the most variable of the characters.

With exception of the figures given by Küchenmeister (1852), the mean magnitude of the large hooks of *T. serrata*, as observed at Lincoln, is above the upper limits given by the authors quoted on page 12, Part I. It is different in the case of the small hooks, however, the mean magnitude here being not far above the average of the mean found by above-quoted authors.

In the case of *T. serialis*, the minimum of the large hooks is practically the minimum observed elsewhere, while the maximum is far above the maxima given on page 12, Part I. The small hooks average somewhat less.

## FRATERNAL CORRELATION

A question which is of great importance now arises: How large a proportion of the total variability does each head exhibit? If, by the standard deviation of an individual, we mean the average of the standard deviations of the individual heads, as found from tables I and II, we have the following results:

*Taenia serrata.*—The standard deviation of the individual large hook is 4.9, while the standard deviation of all the hooks is 9.62, whence the individual variability is about 51 per cent of the whole.

The standard deviation of the individual small hook is 4.1, while that of the type is 7.59, or the individual here exhibits 54 per cent of the total variability.

*Taenia serialis.*—For the large hooks we find the individual variability to be 4.1, and the type variability to be 7.07, or 58 per cent of the total variability is found in the individual.

The small hooks give us a mean standard deviation of 4.6, which is 65 per cent of the total variability. If, however, we omit the evidently abnormal case (6), we have the mean S. D. =3.6, and the individual variability is 51 per cent of the total variability.

The closeness with which these results agree is very remarkable. In order that they may be compared more readily, they are tabulated below.

| | | S. D. OF IND. | S. D. OF TYPE | PERCENTAGE VARIABILITY |
|---|---|---|---|---|
| *Taenia serrata.* | Large hooks.. | 4.9 | 9.62 | 51 |
| | Small hooks.. | 4.1 | 7.59 | 54 |
| *Taenia serialis.* | Large hooks.. | 4.1 | 7.07 | 58 |
| | Small hooks.. | 3.6(4.6?) | 7.04 | 51 (65?) |

CORRELATION OF LARGE AND SMALL HOOKS

Another question of importance is this: From the mean of the large hooks of any worm can we predict within reasonable limits the mean of the small hooks of that worm? To determine this, correlation tables were made in which the means of the large hooks of each head were entered as subject, and the corresponding means of the small hooks as the relative. In this manner the correlation existing between the large and the small hooks of a worm was found to be .3 for *T. serrata,* and .38 for *T. serialis.* The probable errors of these determinations are $\pm.11$, and $\pm.14$ respectively, a trifle over one-third of the correlation in each case, not sufficiently large to destroy it. We thus see that the correlation between the large and the small hooks of a worm is a real, though not very large quantity.

SUMMARY

The results obtained from these mathematical considerations may be summed up as follows:

1. There exists a quite high correlation between characters *a* and *b* in both the large and the small hooks of both species of tapeworms, it being on the average about .7.

The correlation between *a* and *c* is also fairly large, about .5.

The correlations of *c* to *b* and *d* are small.

2. As the hook increases in length, its strength increases relatively faster than the length of its claw.

3. The length is uniformly the least variable part of the hook, while the curvature of the hook is on the whole the most variable.

4. The specimens of both *T. serrata* and *T. serialis* found here have their small hooks approximately of the size found elsewhere, while in the dimensions of the large hooks they excel greatly.

5. The percentage of the total variability exhibited by the individual is nearly constant, and amounts to a little over 50 per cent.

6. The correlation between the large and the small hooks on the same head is .30±.11 for *T. serrata,* and .38±.14 for *T. serialis.*

TABLE I

Hooks of *Taenia Serrata*

| | LARGE HOOKS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HEAD NO. | 294 | 291 | 288 | 285 | 282 | 279 | 276 | 273 | 270 | 267 | 264 | 261 | 258 | 255 | 252 | 249 | 246 | Total |
| 1 | 1 | 4 | ... | 3 | 1 | 6 | 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ..... |
| 2 | ... | ... | 1 | 5 | 1 | 5 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ..... |
| 3 | ... | ... | 1 | ... | ... | 1 | 2 | 1 | 2 | 2 | ... | ... | ... | ... | ... | ... | ... | ..... |
| 4 | ... | ... | 1 | ... | ... | ... | 1 | ... | 1 | 2 | 4 | 2 | ... | 2 | ... | ... | ... | ..... |
| 5 | ... | ... | 1 | ... | ... | 1 | 1 | 1 | ... | ... | ... | 2 | 1 | 5 | 2 | 4 | 1 | ..... |
| 6 | ... | ... | ... | 1 | ... | 5 | 3 | 3 | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ..... |
| 7 | ... | ... | ... | ... | 1 | 1 | 1 | 3 | 2 | 5 | 5 | ... | ... | ... | ... | ... | ... | ..... |
| 8 | ... | ... | ... | ... | 2 | 2 | 3 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ..... |
| 9 | ... | ... | ... | ... | 3 | 10 | 5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ..... |
| 10 | ... | ... | ... | ... | ... | 1 | ... | ... | 1 | 1 | 5 | 9 | ... | ... | ... | ... | ... | ..... |
| 11 | ... | ... | ... | ... | ... | 2 | 2 | 1 | 5 | 3 | ... | ... | ... | ... | ... | ... | ... | ..... |
| 12 | ... | ... | ... | ... | ... | 2 | 4 | 3 | 2 | 4 | 5 | ... | ... | ... | ... | ... | ... | ..... |
| 13 | ... | ... | ... | ... | ... | ... | 1 | 4 | ... | 1 | 1 | 1 | ... | ... | 1 | ... | ... | ..... |
| 14 | ... | ... | ... | ... | ... | ... | 2 | ... | ... | 1 | 1 | 2 | ... | ... | ... | ... | ... | ..... |
| 15 | ... | ... | ... | ... | ... | ... | 1 | 1 | 4 | 2 | 2 | 4 | 3 | ... | 1 | ... | ... | ..... |
| 16 | ... | ... | ... | ... | ... | ... | 1 | 3 | 2 | 1 | ... | ... | ... | ... | ... | ... | ... | ..... |
| 17 | ... | ... | ... | ... | ... | ... | 1 | ... | 4 | 4 | 3 | 1 | ... | ... | 1 | ... | ... | ..... |
| 18 | ... | ... | ... | ... | ... | ... | ... | 1 | 2 | 1 | 2 | 7 | 1 | ... | ... | ... | ... | ..... |
| 19 | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | 1 | 4 | 6 | 5 | ... | 1 | ... | ... | ..... |
| 20 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | 3 | 6 | 1 | 1 | ... | ... | ... | ..... |
| 21 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 3 | 6 | 3 | 2 | 2 | ... | ... | ... | ..... |
| 22 | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 2 | 4 | 3 | ... | 1 | ... | 1 | ... | ..... |
| 23 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 5 | 2 | ... | ... | ... | ... | ... | ..... |
| 24 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 7 | 1 | 3 | 1 | ... | ... | ..... |
| 25 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 3 | 4 | 3 | ... | ... | ... | ..... |
| 26 | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 5 | 6 | 2 | 3 | 3 | ... | ..... |
| 27 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 5 | 7 | 3 | ... | ..... |
| 28 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | 3 | 2 | 1 | 1 | ... | ... | ..... |
| Total. | 1 | 4 | 4 | 9 | 8 | 36 | 34 | 23 | 31 | 36 | 53 | 66 | 27 | 25 | 19 | 11 | 1 | 388 |

TABLE I—*Continued*

Hooks of *Taenia Serrata*

| | SMALL HOOKS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HEAD NO. | 177 | 174 | 171 | 168 | 165 | 162 | 159 | 156 | 153 | 150 | 147 | 144 | 141 | 138 | 135 | 132 | Total |
| 1 | 2 | 2 | 5 | 4 | 2 | ... | 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ..... |
| 2 | ... | ... | ... | ... | ... | 1 | ... | 2 | ... | ... | 6 | 3 | ... | ... | ... | ... | ..... |
| 3 | ... | ... | ... | ... | ... | ... | 1 | 3 | 4 | ... | 5 | ... | ... | ... | ... | ... | ..... |
| 4 | ... | ... | ... | ... | ... | 2 | 3 | 5 | 1 | ... | 1 | 1 | ... | ... | ... | ... | ..... |
| 5 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | 2 | 2 | 3 | 1 | 4 | 1 | ..... |
| 6 | ... | ... | ... | ... | 3 | 2 | 4 | 2 | ... | 1 | 1 | ... | ... | ... | ... | ... | ..... |
| 7 | ... | ... | ... | ... | ... | 1 | 4 | 6 | 2 | 1 | ... | ... | ... | ... | ... | ... | ..... |
| 8 | ... | ... | ... | 1 | ... | ... | 3 | 4 | 4 | 1 | ... | ... | ... | ... | ... | ... | ..... |
| 9 | ... | ... | ... | ... | 1 | 2 | 2 | 3 | 6 | 2 | ... | ... | ... | ... | ... | ... | ..... |
| 10 | ... | ... | ... | ... | ... | ... | 3 | 8 | 2 | 3 | ... | ... | ... | ... | ... | ... | ..... |
| 11 | ... | ... | ... | ... | ... | 2 | 4 | 2 | 5 | ... | 1 | 1 | ... | ... | ... | ... | ..... |
| 12 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 3 | 7 | 4 | 2 | ... | ..... |
| 13 | ... | ... | ... | ... | 1 | 2 | 3 | 2 | 2 | 2 | ... | ... | ... | ... | ... | ... | ..... |
| 14 | ... | ... | ... | ... | ... | ... | 3 | 1 | 4 | 2 | ... | ... | ... | ... | ... | ... | ..... |
| 15 | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 3 | 2 | 2 | 2 | ... | ... | ... | ..... |
| 16 | ... | ... | ... | ... | ... | ... | 1 | 4 | 2 | ... | 1 | ... | ... | ... | ... | ... | ..... |
| 17 | ... | ... | ... | ... | ... | ... | 1 | 1 | 3 | 5 | 7 | 1 | ... | ... | ... | .. | ..... |
| 18 | ... | ... | ... | ... | ... | ... | 1 | 4 | .. | 2 | 2 | 2 | ... | ... | ... | ... | ..... |
| 19 | ... | ... | ... | ... | ... | ... | ... | 2 | 4 | 1 | 3 | 1 | ... | ... | ... | ... | ..... |
| 20 | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 2 | 2 | 1 | 3 | 1 | ... | ... | ..... |
| 21 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 1 | 5 | 3 | 3 | ... | ... | ..... |
| 22 | ... | ... | ... | ... | ... | ... | ... | 1 | 4 | 5 | 2 | ... | ... | ... | ... | ... | ..... |
| 23 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | 6 | 6 | ... | 1 | ... | ... | ..... |
| 24 | ... | ... | ... | ... | ... | 2 | 6 | 2 | 2 | 1 | ... | ... | ... | ... | ... | ... | ..... |
| 25 | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | 2 | 3 | ... | ... | ... | ... | ... | ..... |
| 26 | ... | ... | ... | ... | ... | ... | 1 | ... | 4 | 3 | 7 | 2 | 2 | ... | ... | ... | ..... |
| 27 | ... | ... | ... | ... | ... | ... | 2 | 6 | 4 | 3 | 5 | ... | ... | ... | ... | ... | ..... |
| 28 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 8 | ... | ... | ... | ... | ... | ..... |
| Total .. | 2 | 2 | 6 | 5 | 7 | 14 | 44 | 62 | 58 | 46 | 66 | 30 | 20 | 10 | 6 | 1 | 375 |

TABLE II

Hooks of *Taenia Serialis*

| HEAD NO. | LARGE HOOKS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 175 | 172 | 169 | 166 | 163 | 160 | 157 | 154 | 151 | 148 | 145 | 142 | 139 | Total |
| 1 | 1 | .... | 2 | 2 | .... | 2 | .... | .... | 1 | .... | .... | .... | .... | ..... |
| 2 | .... | 1 | 2 | .... | .... | 1 | .... | .... | .... | .... | .... | .... | .... | ..... |
| 3 | .... | .... | .... | 1 | 2 | 1 | 1 | 1 | .... | .... | .... | .... | .... | ..... |
| 4 | .... | .... | .... | 1 | 1 | 1 | .... | .... | 1 | .... | .... | .... | .... | ..... |
| 5 | .... | .... | .... | .... | 2 | 2 | 3 | 1 | 2 | 1 | .... | .... | .... | ..... |
| 6 | .... | .... | .... | .... | 1 | 3 | 2 | 4 | 2 | .... | 1 | .... | .... | ..... |
| 7 | .... | .... | .... | .... | 1 | 1 | 1 | 3 | 3 | .... | .... | .... | .... | ..... |
| 8 | .... | .... | .... | .... | .... | 1 | 1 | 4 | 3 | 1 | 1 | .... | .... | ..... |
| 9 | .... | .... | .... | .... | .... | 1 | 1 | 4 | .... | 3 | 2 | .... | .... | ..... |
| 10 | .... | .... | .... | .... | .... | 3 | 2 | 2 | .... | .... | .... | .... | .... | ..... |
| 11 | .... | .... | .... | .... | .... | .... | 1 | 1 | 2 | .... | 1 | .... | .... | ..... |
| 12 | .... | .... | .... | .... | .... | .... | 2 | 4 | 3 | 3 | .... | .... | .... | ..... |
| 13 | .... | .... | .... | .... | .... | .... | .... | 1 | .... | 5 | 1 | .... | .... | ..... |
| 14 | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 3 | 3 | 2 | .... | ..... |
| 15 | .... | .... | .... | .... | .... | .... | .... | .... | 1 | .... | 2 | 5 | 1 | ..... |
| Total. | 1 | 1 | 4 | 4 | 7 | 16 | 14 | 25 | 21 | 16 | 11 | 7 | 1 | 128 |

TABLE II—*Continued*

Hooks of *Taenia Serialis*

SMALL HOOKS

| HEAD NO. | 114 | 111 | 108 | 105 | 102 | 99 | 96 | 93 | 90 | 87 | 84 | 81 | 78 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .... | 1 | 3 | 1 | .... | 3 | .... | .... | .... | .... | ... | .... | .... | ..... |
| 2 | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | ..... |
| 3 | .... | 3 | 2 | 1 | .... | .... | .... | .... | .... | .... | .... | .... | .... | ..... |
| 4 | .... | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1 | ..... |
| 5 | .... | .... | .... | 1 | 2 | 4 | 1 | .... | .... | .... | .... | .... | .... | ..... |
| 6 | 2 | 2 | 3 | 1 | 2 | 2 | .... | .... | .... | .... | .... | .... | .... | ..... |
| 7 | .... | .... | .... | 1 | 2 | 3 | 3 | .... | 1 | .... | .... | .... | .... | ..... |
| 8 | .... | .... | .... | 1 | 2 | 5 | 1 | .... | 1 | .... | .... | .... | .... | ..... |
| 9 | .... | 1 | 1 | .... | 2 | 1 | 3 | .... | .... | .... | .... | .... | .... | ..... |
| 10 | .... | 1 | .... | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | ..... |
| 11 | 1 | 1 | 1 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | ..... |
| 12 | .... | .... | .... | .... | 1 | 2 | 3 | 3 | .... | 1 | 2 | .... | .... | ..... |
| 13 | .... | .... | .... | .... | 2 | 1 | 2 | 7 | .... | .... | .... | .... | .... | ..... |
| 14 | .... | .... | .... | .... | .... | 4 | 2 | 1 | 3 | .... | .... | .... | .... | ..... |
| 15 | .... | .... | .... | .... | 1 | 2 | 2 | 1 | .... | 2 | .... | .... | .... | ..... |
| Total. | 3 | 11 | 10 | 7 | 17 | 27 | 17 | 12 | 5 | 3 | 2 | .... | 1 | 115 |

TABLE III

Correlation of characters *a* and *b* of the small hooks of *Taenia Serrata*

| Subject Classes, Character *a* | | | Relative Classes, Character *b* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $X$ | $Y'$ | —14 80 | —11 83 | —8 86 | —5 89 | —2 92 | 0 95 | 3 98 | 6 101 | 9 104 | 12 107 | 15 110 | 18 113 | 21 116 | Total |
| | —19 | 132 | .... | .... | 1 | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... | 1 |
| | —16 | 135 | 1 | 3 | ... | 2 | ... | ... | ... | ... | ... | II | ... | ... | ... | 6 |
| | —13 | 138 | I | 2 | 3 | 4 | ... | 1 | ... | ... | ... | | ... | ... | ... | 10 |
| | —10 | 141 | | 3 | 9 | 4 | 3 | 1 | ... | ... | ... | ... | ... | ... | ... | 20 |
| | — 7 | 144 | .... | 3 | 7 | 9 | 4 | 6 | 1 | ... | ... | ... | ... | ... | ... | 30 |
| | — 4 | 147 | .... | 2 | 9 | 11 | 17 | 13 | 9 | 3 | ... | ... | 2 | ... | ... | 66 |
| | — 1 | 150 | .... | .... | 3 | 6 | 9 | 12 | 8 | ... | 2 | 2 | ... | ... | ... | 42 |
| | 1 | 153 | .... | 1 | 4 | 2 | 19 | 9 | 12 | 6 | 4 | 1 | ... | ... | ... | 58 |
| | 4 | 156 | 1 | .... | ... | 7 | 12 | 10 | 15 | 9 | 5 | ... | ... | 1 | 2 | 62 |
| | 7 | 159 | .... | .... | ... | 2 | 4 | 9 | 8 | 12 | 5 | 2 | 1 | ... | 1 | 44 |
| | 10 | 162 | .... | .... | ... | ... | 2 | ... | 2 | 4 | 4 | ... | 2 | ... | ... | 14 |
| | 13 | 165 | .... | III | ... | ... | ... | 1 | 1 | 2 | 2 | 1 | IV | ... | ... | 7 |
| | 16 | 168 | .... | | ... | ... | ... | ... | ... | 2 | 1 | 2 | | ... | ... | 5 |
| | 19 | 171 | .... | .... | ... | ... | 1 | ... | ... | 1 | ... | ... | 3 | ... | 1 | 6 |
| | 22 | 174 | .... | .... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 1 | ... | 2 |
| | 25 | 177 | .... | .... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | ... | 2 |
| | Tot'l | .... | 2 | 14 | 36 | 47 | 71 | 62 | 56 | 40 | 23 | 9 | 8 | 3 | 4 | 375 |

$\Sigma_1^4(fXY') = 5030 - 387 - 587 + 7254$; $-\Sigma_1(fX) - \Sigma_1(fY) + \Sigma_1(f)$
$= 757 + 659 + 115$; $-\Sigma_2(fY) - \Sigma_3(fX) = -144 - 187$.

$$13510 \div 375 = 36.03$$

$\xi\eta = .01 \times .1 = 0$, $\sigma_x \sigma_y = 6.8 \times 7.59 = 51.61$; $36.03 \div 51.61 = .70 = \rho$

Subject classes { Mean = 151.99; $\sigma_x$ = 7.59; $V_x$ = 4.99% }

Relative classes { Mean = 94.90; $\sigma_y$ = 6.80; $V_y$ = 7.17% }

TABLE IV

Correlation of characters *a* and *c* of the small hooks of *Taenia Serrata*

| Character *a* | Character *c* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 65 | 68 | 71 | 74 | 77 | 80 | 83 | 86 | 89 | 92 | 95 | 98 | 101 | 104 | Total |
| 132 | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | .... | .... | 1 |
| 135 | ... | ... | ... | 1 | 1 | 1 | 1 | 2 | ... | ... | ... | ... | .... | .... | 6 |
| 138 | ... | ... | 1 | 2 | 2 | 2 | 2 | 1 | ... | ... | ... | ... | .... | .... | 10 |
| 141 | ... | ... | ... | 1 | 3 | 3 | 8 | 2 | 3 | ... | ... | ... | .... | .... | 20 |
| 144 | ... | ... | ... | 4 | ... | 8 | 7 | 7 | 4 | ... | ... | ... | .... | .... | 30 |
| 147 | 1 | ... | ... | 4 | 8 | 11 | 9 | 17 | 12 | 3 | 1 | ... | .... | .... | 66 |
| 150 | ... | ... | ... | 3 | 1 | 11 | 6 | 8 | 10 | 3 | ... | ... | .... | .... | 42 |
| 153 | ... | ... | ... | 3 | 1 | 2 | 13 | 15 | 15 | 6 | 2 | ... | 1 | .... | 58 |
| 156 | ... | ... | ... | 2 | 1 | 4 | 14 | 20 | 16 | 2 | 2 | ... | 1 | .... | 62 |
| 159 | ... | ... | ... | ... | 1 | 2 | 3 | 14 | 9 | 4 | 10 | ... | 1 | .... | 44 |
| 162 | ... | ... | ... | ... | ... | 2 | 1 | 1 | 3 | 2 | 3 | 1 | .... | .... | 14 |
| 165 | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | 2 | 3 | ... | .... | .... | 7 |
| 168 | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | 1 | 1 | 1 | .... | .... | 5 |
| 171 | ... | ... | ... | ... | ... | ... | ... | ... | 2 | 2 | 1 | ... | .... | 1 | 6 |
| 174 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | ... | .... | .... | 2 |
| 177 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 1 | .... | 2 |
| Total | 1 | ... | 1 | 20 | 19 | 47 | 65 | 89 | 77 | 26 | 23 | 2 | 4 | 1 | 375 |

TABLE V

Correlation of characters *c* and *d* of the small hooks of *Taenia Serrata*

| Character *d* | Character *c* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 65 | 68 | 71 | 74 | 77 | 80 | 83 | 86 | 89 | 92 | 95 | 98 | 101 | 104 | Total |
| 32 | ... | ... | ... | ... | 1 | ... | ... | 4 | 2 | ... | ... | ... | .... | .... | 7 |
| 35 | ... | ... | ... | 1 | 2 | 4 | 12 | 16 | 9 | 1 | 1 | ... | .... | .... | 46 |
| 38 | ... | ... | ... | 4 | 5 | 20 | 21 | 26 | 18 | 7 | 3 | ... | 2 | .... | 106 |
| 41 | ... | ... | ... | 8 | 8 | 14 | 25 | 22 | 26 | 5 | 6 | ... | 1 | .... | 115 |
| 44 | 1 | ... | 1 | 5 | 3 | 9 | 5 | 18 | 18 | 10 | 11 | ... | .... | 1 | 82 |
| 47 | ... | ... | ... | 2 | ... | ... | 2 | 3 | 4 | 3 | 2 | 2 | 1 | .... | 19 |
| Total | 1 | ... | 1 | 20 | 19 | 47 | 65 | 89 | 77 | 26 | 23 | 2 | 4 | 1 | 375 |

TABLE VI

Correlation of characters *b* and *c* of the small hooks of *Taenia Serrata*

Character *b*

| Character *c* | 80 | 83 | 86 | 89 | 92 | 95 | 98 | 101 | 104 | 107 | 110 | 113 | 116 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | ... | ... | ... | ... | ... | ... | ... | .... | .... | .... | 1 | .... | .... | 1 |
| 68 | ... | ... | ... | ... | ... | ... | ... | .... | .... | .... | .... | .... | .... | ..... |
| 71 | ... | ... | ... | ... | ... | 1 | ... | .... | .... | .... | .... | .... | .... | 1 |
| 74 | ... | ... | ... | 4 | 3 | 1 | 2 | 1 | 3 | 3 | .... | 1 | 2 | 20 |
| 77 | ... | ... | ... | 4 | 4 | 4 | 5 | 1 | .... | .... | .... | .... | 1 | 19 |
| 80 | 1 | 1 | 3 | 7 | 7 | 11 | 7 | 4 | 1 | 3 | 2 | .... | .... | 47 |
| 83 | ... | 3 | 10 | 5 | 10 | 9 | 15 | 6 | 6 | 1 | .... | .... | .... | 65 |
| 86 | ... | 6 | 11 | 6 | 25 | 14 | 7 | 11 | 7 | .... | 2 | .... | .... | 89 |
| 89 | ... | 2 | 6 | 16 | 12 | 12 | 14 | 9 | 2 | 1 | 2 | 1 | .... | 77 |
| 92 | ... | 2 | 6 | 3 | 4 | 3 | 2 | 2 | 1 | .... | 1 | 1 | 1 | 26 |
| 95 | ... | ... | ... | 1 | 4 | 7 | 4 | 4 | 3 | .... | .... | .... | .... | 23 |
| 98 | ... | ... | ... | ... | 1 | ... | ... | 1 | .... | .... | .... | .... | .... | 2 |
| 101 | 1 | ... | ... | 1 | ... | ... | ... | 1 | .... | 1 | .... | .... | .... | 4 |
| 104 | ... | ... | ... | ... | 1 | ... | ... | .... | .... | .... | .... | .... | .... | 1 |
| Total | 2 | 14 | 36 | 47 | 71 | 62 | 56 | 40 | 23 | 9 | 8 | 3 | 4 | 375 |

TABLE VII

Correlation of characters *a* and *b* of the large hooks of *Taenia Serrata*

Character *b*

| Character *a* | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 176 | 179 | 182 | 185 | 188 | 191 | 194 | 197 | 200 | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 246 | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 |
| 249 | ... | ... | ... | 1 | 1 | 1 | 4 | 3 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 11 |
| 252 | 1 | ... | 1 | ... | 1 | ... | 6 | 5 | 4 | ... | 2 | ... | ... | ... | ... | ... | ... | ... | ... | 19 |
| 255 | ... | ... | ... | ... | ... | 2 | 6 | 6 | 4 | 3 | 2 | 1 | ... | ... | ... | ... | ... | ... | ... | 25 |
| 258 | ... | ... | ... | ... | ... | 1 | 7 | 5 | 6 | 2 | 4 | 1 | 1 | ... | ... | ... | ... | ... | ... | 27 |
| 261 | ... | ... | ... | ... | ... | 3 | 10 | 9 | 14 | 14 | 11 | 5 | ... | ... | ... | ... | ... | ... | ... | 66 |
| 264 | ... | ... | ... | 1 | ... | 1 | 5 | 6 | ... | 15 | 13 | 12 | ... | ... | ... | ... | ... | ... | ... | 53 |
| 267 | ... | ... | ... | ... | ... | 1 | 4 | 4 | 3 | 3 | 5 | 7 | 7 | 2 | ... | ... | ... | ... | ... | 36 |
| 270 | ... | ... | ... | ... | ... | ... | 1 | 2 | 2 | 4 | 6 | 8 | 4 | 3 | 1 | ... | ... | ... | ... | 31 |
| 273 | ... | ... | ... | ... | ... | 1 | 1 | 5 | 3 | 3 | 3 | 2 | 2 | ... | 3 | ... | ... | ... | ... | 23 |
| 276 | ... | ... | ... | ... | ... | ... | 1 | 2 | 5 | 4 | 8 | 5 | 4 | 4 | ... | 1 | ... | ... | ... | 34 |
| 279 | ... | ... | ... | ... | ... | ... | 2 | 2 | 2 | 4 | 3 | 7 | 2 | 7 | 6 | 1 | ... | ... | ... | 36 |
| 282 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 2 | 1 | 1 | 1 | ... | 2 | ... | ... | ... | 8 |
| 285 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 1 | ... | ... | ... | ... | 5 | 1 | 1 | ... | 9 |
| 288 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | ... | 2 | ... | ... | ... | ... | 4 |
| 291 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 2 | ... | 1 | 1 | 4 |
| 294 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 |
| Tot'l | 1 | ... | 1 | 2 | 2 | 11 | 47 | 51 | 44 | 52 | 61 | 50 | 21 | 17 | 12 | 11 | 1 | 3 | 1 | 388 |

TABLE VIII

Correlation of characters *a* and *c* of the large hooks of *Taenia Serrata*

| Character *a* | Character *c* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | 93 | 96 | 99 | 102 | 105 | 108 | 111 | 114 | 117 | 120 | 123 | 126 | 129 | 132 | 135 | Total |
| 246 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | 1 |
| 249 | 3 | ... | 2 | 1 | 1 | 1 | 2 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 11 |
| 252 | 1 | ... | 3 | 9 | 1 | 3 | 1 | ... | 1 | ... | ... | ... | ... | ... | ... | ... | 19 |
| 255 | ... | 1 | 4 | 9 | 2 | 3 | 5 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 25 |
| 258 | 1 | ... | 3 | 2 | 4 | 3 | 6 | 8 | ... | ... | ... | ... | ... | ... | ... | ... | 27 |
| 261 | ... | ... | 2 | 15 | 5 | 13 | 15 | 10 | 5 | 1 | ... | ... | ... | ... | ... | ... | 66 |
| 264 | ... | ... | 3 | 9 | 4 | 11 | 13 | 7 | 4 | 1 | 1 | ... | ... | ... | ... | ... | 53 |
| 267 | ... | 3 | 2 | 5 | 1 | 6 | 5 | 3 | 7 | 3 | 1 | ... | ... | ... | ... | ... | 36 |
| 270 | ... | ... | 1 | 3 | 5 | 6 | 6 | 5 | 2 | 1 | ... | ... | ... | ... | ... | ... | 31 |
| 273 | ... | ... | ... | 1 | 1 | 1 | 1 | 5 | 4 | 1 | 8 | ... | ... | 1 | ... | ... | 23 |
| 276 | ... | 1 | 1 | 1 | 2 | 4 | 1 | 4 | 9 | 3 | 5 | 2 | 1 | ... | ... | ... | 34 |
| 279 | ... | ... | ... | ... | ... | 4 | 6 | 6 | 8 | 1 | ... | 3 | 6 | 1 | ... | 1 | 36 |
| 282 | ... | ... | ... | 1 | ... | 1 | 2 | 1 | ... | 1 | 2 | ... | ... | ... | ... | ... | 8 |
| 285 | ... | ... | ... | ... | 1 | 3 | 2 | ... | ... | 1 | ... | ... | 1 | ... | 1 | ... | 9 |
| 288 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 | ... | ... | 1 | ... | ... | 4 |
| 291 | ... | ... | ... | ... | ... | ... | 1 | 1 | 1 | 1 | ... | ... | ... | ... | ... | ... | 4 |
| 294 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 1 |
| Tot. | 5 | 5 | 21 | 56 | 27 | 59 | 66 | 53 | 41 | 16 | 20 | 6 | 8 | 3 | 1 | 1 | 388 |

TABLE IX

Correlation of characters *c* and *d* of the large hooks of *Taenia Serrata*

| Character *d* | Character *c* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | 93 | 96 | 99 | 102 | 105 | 108 | 111 | 114 | 117 | 120 | 123 | 126 | 129 | 132 | 135 | Total |
| 41 | 1 | ... | 2 | 4 | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 8 |
| 44 | 3 | 2 | 4 | 5 | 4 | 4 | 5 | 6 | 2 | ... | ... | ... | 1 | ... | ... | ... | 36 |
| 47 | ... | 3 | 6 | 24 | 11 | 23 | 22 | 11 | 19 | 4 | 3 | ... | ... | 1 | ... | ... | 127 |
| 50 | 1 | ... | 6 | 18 | 10 | 16 | 24 | 22 | 6 | 3 | 7 | 1 | 2 | ... | 1 | ... | 117 |
| 53 | ... | ... | 3 | 5 | 2 | 13 | 12 | 11 | 12 | 6 | 9 | 3 | 5 | 1 | ... | ... | 82 |
| 56 | ... | ... | ... | ... | ... | 3 | 3 | 2 | 2 | 3 | 1 | 2 | ... | 1 | ... | 1 | 18 |
| Tot'l | 5 | 5 | 21 | 56 | 27 | 59 | 66 | 53 | 41 | 16 | 20 | 6 | 8 | 3 | 1 | 1 | 388 |

TABLE X

Correlation of characters *b* and *c* of the large hooks of *Taenia Serrata*

Character *b*

| Character *c* | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 176 | 179 | 182 | 185 | 188 | 191 | 194 | 197 | 200 | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | ... | ... | ... | ... | ... | ... | 1 | 2 | ... | ... | 2 | ... | ... | ... | ... | ... | ... | ... | ... | 5 |
| 93 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 3 | 1 | ... | ... | ... | ... | ... | 5 |
| 96 | ... | ... | ... | ... | ... | ... | ... | 2 | 4 | ... | 4 | 5 | 2 | 3 | ... | 1 | ... | ... | ... | 21 |
| 99 | ... | ... | ... | ... | ... | 1 | 6 | 6 | 3 | 6 | 13 | 15 | 3 | 2 | 1 | ... | ... | ... | ... | 56 |
| 102 | ... | ... | ... | ... | ... | 1 | 1 | 1 | 3 | 7 | 4 | 3 | 2 | 2 | 2 | 1 | ... | ... | ... | 27 |
| 105 | ... | ... | ... | ... | ... | ... | 5 | 3 | 9 | 10 | 12 | 9 | 4 | 1 | 3 | 2 | ... | 1 | ... | 59 |
| 108 | ... | ... | ... | ... | 1 | 3 | 6 | 12 | 8 | 13 | 7 | 3 | 3 | 3 | 1 | 4 | 1 | ... | 1 | 66 |
| 111 | ... | ... | ... | 1 | 1 | 2 | 12 | 8 | 6 | 3 | 5 | 6 | 1 | 3 | 2 | 1 | ... | 2 | ... | 53 |
| 114 | ... | ... | 1 | 1 | ... | 1 | 8 | 5 | 2 | 5 | 6 | 6 | 3 | 2 | 1 | ... | ... | ... | ... | 41 |
| 117 | ... | ... | ... | ... | ... | 1 | 3 | 2 | 2 | 1 | 5 | ... | ... | ... | ... | 2 | ... | ... | ... | 16 |
| 120 | ... | ... | ... | ... | ... | 1 | 2 | 6 | 5 | 1 | 2 | 2 | ... | ... | 1 | ... | ... | ... | ... | 20 |
| 123 | 1 | ... | ... | ... | ... | ... | ... | 1 | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 6 |
| 126 | ... | ... | ... | ... | ... | ... | 3 | 1 | 1 | 2 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 8 |
| 129 | ... | ... | ... | ... | ... | 1 | ... | 1 | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | 3 |
| 132 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 |
| 135 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | 1 |
| Tot'l | 1 | ... | 1 | 2 | 2 | 11 | 47 | 51 | 44 | 52 | 61 | 50 | 21 | 17 | 12 | 11 | 1 | 3 | 1 | 388 |

TABLE XI

Correlation of the characters *a* and *b* of the large hooks of *Taenia Serialis*

Character *b*

| Character *a* | 85 | 88 | 91 | 94 | 97 | 100 | 103 | 106 | 109 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 139 | .... | 1 | .... | ..... | ..... | ..... | ..... | ..... | ..... | 1 |
| 142 | 2 | .... | 5 | ..... | ..... | ..... | ..... | ..... | ..... | 7 |
| 145 | 1 | 1 | 4 | 3 | 1 | 1 | ..... | ..... | ..... | 11 |
| 148 | .... | .... | 3 | 8 | 3 | 2 | ..... | ..... | ..... | 16 |
| 151 | .... | .... | 3 | 10 | 5 | ..... | 2 | ..... | 1 | 21 |
| 154 | .... | .... | 1 | 3 | 8 | 6 | 6 | 1 | ..... | 25 |
| 157 | .... | .... | .... | ..... | 4 | 5 | 4 | 1 | ..... | 14 |
| 160 | .... | .... | .... | 2 | 1 | 5 | 6 | 2 | ..... | 16 |
| 163 | .... | .... | .... | ..... | 1 | 1 | 3 | 1 | 1 | 7 |
| 166 | .... | .... | .... | ..... | ..... | ..... | 1 | 2 | 1 | 4 |
| 169 | .... | .... | .... | ..... | 2 | ..... | 1 | ..... | 1 | 4 |
| 172 | .... | .... | .... | ..... | ..... | ..... | 1 | ..... | ..... | 1 |
| 175 | .... | .... | .... | ..... | ..... | ..... | ..... | 1 | ..... | 1 |
| Total | 3 | 2 | 16 | 26 | 25 | 20 | 24 | 8 | 4 | 128 |

TABLE XII

Correlation of characters *a* and *c* of the large hooks of *Taenia Serialis*

| Character *a* | Character *c* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 61 | 64 | 67 | 70 | 73 | 76 | 79 | 82 | Total |
| 139 | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... | 1 |
| 142 | ..... | ..... | 3 | 2 | 2 | ..... | ..... | ..... | 7 |
| 145 | ..... | 1 | ..... | 3 | 5 | 2 | ..... | ..... | 11 |
| 148 | 1 | ..... | 1 | 2 | 10 | 2 | ..... | ..... | 16 |
| 151 | ..... | ..... | 2 | 7 | 8 | 4 | ..... | ..... | 21 |
| 154 | ..... | ..... | ..... | 6 | 12 | 6 | 1 | ..... | 25 |
| 157 | ..... | ..... | ..... | 2 | 8 | 4 | ..... | ..... | 14 |
| 160 | ..... | ..... | ..... | 3 | 5 | 7 | 1 | ..... | 16 |
| 163 | ..... | ..... | ..... | 1 | 2 | 2 | 2 | ..... | 7 |
| 166 | ..... | ..... | ..... | ..... | ..... | 4 | ..... | ..... | 4 |
| 169 | ..... | ..... | ..... | ..... | ..... | ..... | 2 | 2 | 4 |
| 172 | ..... | ..... | ..... | ..... | .. .. | ..... | 1 | ..... | 1 |
| 175 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | 1 |
| Total | 1 | 1 | 7 | 26 | 51 | 32 | 7 | 3 | 128 |

TABLE XIII

Correlation of characters *c* and *d* of the large hooks of *Taenia Serialis*

| Character *d* | Character *c* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 61 | 64 | 67 | 70 | 73 | 76 | 79 | 82 | Total |
| 25 | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... | 2 |
| 28 | ..... | 1 | 4 | 12 | 17 | 5 | 1 | ..... | 40 |
| 31 | 1 | ..... | 3 | 12 | 30 | 25 | 2 | 2 | 75 |
| 34 | ..... | ..... | ..... | 2 | 2 | 2 | 4 | 1 | 11 |
| Total | 1 | 1 | 7 | 26 | 51 | 32 | 7 | 3 | 128 |

TABLE XIV

Correlation of characters *b* and *c* of the large hooks of *Taenia Serialis*

| Character *c* | Character *b* 85 | 88 | 91 | 94 | 97 | 100 | 103 | 106 | 109 | Tot'l |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | 1 |
| 64 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | 1 |
| 67 | ..... | 1 | 3 | ..... | 3 | ..... | ..... | ..... | ..... | 7 |
| 70 | ..... | ..... | 8 | 4 | 3 | 4 | 4 | 2 | 1 | 26 |
| 73 | 2 | 1 | 3 | 16 | 9 | 7 | 10 | 2 | 1 | 51 |
| 76 | 1 | ..... | 2 | 6 | 5 | 7 | 7 | 3 | 1 | 32 |
| 79 | ..... | ..... | ..... | ..... | 1 | 2 | 3 | ..... | 1 | 7 |
| 82 | ..... | ..... | ..... | ..... | 2 | ..... | ..... | 1 | .... | 3 |
| Tot'l | 3 | 2 | 16 | 26 | 25 | 20 | 24 | 8 | 4 | 128 |

TABLE XV

Correlation of characters *a* and *b* of the small hooks of *Taenia Serialis*

| Character *a* | Character *b* 52 | 55 | 58 | 61 | 64 | 67 | 70 | 73 | 76 | 79 | 82 | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... | 1 |
| 81 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | ..... |
| 84 | 2 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 |
| 87 | .... | 1 | 1 | 1 | .... | .... | .... | .... | .... | .... | .... | 3 |
| 90 | .... | 3 | 1 | 1 | .... | .... | .... | .... | .... | .... | .... | 5 |
| 93 | .... | 3 | 3 | 4 | 2 | .... | .... | .... | .... | .... | .... | 12 |
| 96 | .... | 1 | 1 | 9 | 5 | 1 | .... | .... | .... | .... | .... | 17 |
| 99 | .... | 2 | 2 | 7 | 8 | 3 | 2 | 2 | 1 | .... | .... | 27 |
| 102 | .... | 2 | .... | 1 | 5 | 6 | 2 | 1 | .... | .... | .... | 17 |
| 105 | .... | .... | .... | .... | .... | 1 | 5 | .... | 1 | .... | .... | 7 |
| 108 | .... | .... | .... | .... | .... | 3 | 1 | 3 | 3 | .... | .... | 10 |
| 111 | .... | .... | .... | .... | 1 | 2 | 2 | 2 | 1 | 3 | .... | 11 |
| 114 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2 | 1 | 3 |
| Total | 2 | 12 | 8 | 23 | 22 | 16 | 12 | 8 | 6 | 5 | 1 | 115 |

TABLE XVI

Correlation of characters *c* and *d* of the small hooks of *Taenia Serialis*

| Character *d* | Character *c* 42 | 45 | 48 | 51 | 54 | 57 | 60 | 63 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 19 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | 1 |
| 22 | ..... | ..... | ..... | 1 | 6 | 3 | 1 | ..... | 11 |
| 25 | 1 | 3 | 3 | 13 | 12 | 2 | 2 | 1 | 37 |
| 28 | 1 | 2 | 5 | 15 | 21 | 8 | 2 | 1 | 55 |
| 31 | ..... | 1 | ..... | 3 | 4 | 2 | 1 | ..... | 11 |
| | 2 | 6 | 8 | 32 | 44 | 15 | 6 | 2 | 115 |

TABLE XVII

Correlation of characters *a* and *c* of the small hooks of *Taenia Serialis*

| Character *a* | Character *c* 42 | 45 | 48 | 51 | 54 | 57 | 60 | 63 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 78 | 1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 |
| 81 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 84 | ..... | ..... | ..... | 2 | ..... | ..... | ..... | ..... | 2 |
| 87 | ..... | 1 | ..... | 1 | 1 | ..... | ..... | ..... | 3 |
| 90 | ..... | ..... | ..... | 2 | 3 | ..... | ..... | ..... | 5 |
| 93 | ..... | 1 | 2 | 2 | 5 | 2 | ..... | ..... | 12 |
| 96 | ..... | ..... | 2 | 6 | 8 | 1 | ..... | ..... | 17 |
| 99 | 1 | 2 | 2 | 9 | 10 | 1 | 2 | ..... | 27 |
| 102 | ..... | 1 | ..... | 3 | 8 | 4 | ..... | 1 | 17 |
| 105 | ..... | 1 | 1 | 1 | 2 | 1 | 1 | ..... | 7 |
| 108 | ..... | ..... | ..... | 3 | 3 | 4 | ..... | ..... | 10 |
| 111 | ..... | ..... | 1 | 2 | 3 | 2 | 3 | ..... | 11 |
| 114 | ..... | ..... | ..... | 1 | 1 | ..... | ..... | 1 | 3 |
| Total | 2 | 6 | 8 | 32 | 44 | 15 | 6 | 2 | 115 |

TABLE XVIII

Correlation of characters *b* and *c* of the small hooks of *Taenia Serialis*

| Character *c* | Character *b* 52 | 55 | 58 | 61 | 64 | 67 | 70 | 73 | 76 | 79 | 82 | Tot. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42 | .... | .... | .... | .... | 1 | .... | 1 | .... | .... | .... | .... | 2 |
| 45 | .... | .... | .... | 1 | 1 | .... | .... | 3 | 1 | .... | .... | 6 |
| 48 | .... | .... | .... | 2 | 1 | 1 | 2 | .... | 1 | 1 | .... | 8 |
| 51 | 2 | 3 | 2 | 7 | 6 | 5 | 2 | 2 | .... | 3 | .... | 32 |
| 54 | .... | 5 | 5 | 10 | 10 | 5 | 4 | 1 | 3 | 1 | .... | 44 |
| 57 | .... | 3 | 1 | 1 | 2 | 4 | 1 | 2 | 1 | .... | .... | 15 |
| 60 | .... | .... | .... | 2 | 1 | 1 | 2 | .... | .... | .... | .... | 6 |
| 63 | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | 1 | 2 |
| Total | 2 | 12 | 8 | 23 | 22 | 16 | 12 | 8 | 6 | 5 | 1 | 115 |

## II.—*Examples of Groups*

BY ELLERY WILLIAMS DAVIS

The notion of a group is so simple and so useful an aid to the logical memory that it can well be brought into even rather elementary mathematics. For example, the operations of taking the complement and taking the supplement of an angle generate a group of order 8. To see this,

let $s$ mean supplement-of,
and $c$ mean complement-of;
so that $sc$ means supplement-of-complement-of.

Then,

if $\alpha$ is any angle
we have $s\alpha = \pi - \alpha$, $c\alpha = \pi/2 - \alpha$
$cs\alpha = \alpha - \pi/2$, $sc\alpha = \alpha + \pi/2$
$scs\alpha = 3\pi/2 - \alpha$, $csc\alpha = -\alpha$
$cscs\alpha = \alpha - \pi$, $scsc\alpha = \alpha + \pi$

Two angles like $\alpha \pm \pi$ differing by $2\pi$, or a complete revolution, we regard as the same angle.

It will be found that either $s$ or $c$ performed upon any one of the above seven angles will produce another of them, or $\alpha$. Thus, we have the group of operations

$$G_8 = \{s, c\} = \{1, s, c, sc, cs, scs, csc, scsc\},$$

such that the performance of any two in succession is the same as the performance of some single operation of the group. We call this single operation the product of the other two and construct the multiplication table below.

UNIVERSITY STUDIES, Vol. IV, No. 3, July, 1904.

| | 1 | $s$ | $c$ | $sc$ | $cs$ | $scs$ | $csc$ | $*(sc)^2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | $s$ | $c$ | $sc$ | $cs$ | $scs$ | $csc$ | $(sc)^2$ |
| $s$ | $s$ | 1 | $sc$ | $c$ | $scs$ | $cs$ | $(sc)^2$ | $csc$ |
| $c$ | $c$ | $cs$ | 1 | $csc$ | $s$ | $(sc)^2$ | $sc$ | $scs$ |
| $sc$ | $sc$ | $scs$ | $s$ | $(sc)^2$ | 1 | $csc$ | $c$ | $cs$ |
| $cs$ | $cs$ | $c$ | $csc$ | 1 | $(sc)^2$ | $s$ | $scs$ | $sc$ |
| $*scs$ | $scs$ | $sc$ | $(sc)^2$ | $s$ | $csc$ | 1 | $cs$ | $*c$ |
| $csc$ | $csc$ | $(sc)^2$ | $cs$ | $scs$ | $c$ | $sc$ | 1 | $s$ |
| $(sc)^2$ | $(sc)^2$ | $csc$ | $scs$ | $cs$ | $sc$ | $c$ | $s$ | 1 |

Multiplication is here supposed performed from left to right, multiplicands being taken from the upper border, while multipliers are taken from the left border. We have marked by * in the table

$$scs,\ (sc)^2,\ \text{and}\ c{=}scs\ (sc)^2.$$

In words, the equation just written is

supplement-of-complement-of-supplement
of
supplement-of-complement-of supplement-of-complement-of
is the same as
complement-of.

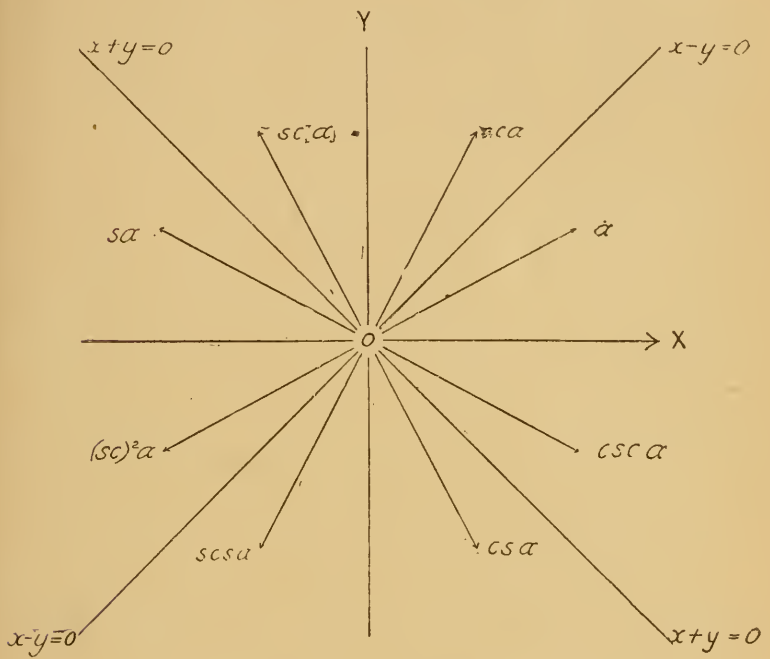
It will be noted that every operation occurs in every line of the table and that the square of every operation except $sc$ and $cs$ is unity, while the product of each of these by the other is unity. That is to say—

1. *The product of all the operations of the group into or by any one of them is again all the operations of the group.*

2. *The group is composed of operations that are either self-reciprocal or reciprocal in pairs.*

These are properties of all groups.

To visualize our results, take an angle $\alpha$, not an integral multiple of $\pi/8$, and place in the standard position, vertex at origen and positive $x$-axis for initial line. If the other angles be likewise thought of as in standard position, their terminal lines will lie as in the diagram below.




Geometrically then—
Multiplication by unity leaves the terminal line alone.
Multiplication by $s$ reflects it upon the $y$-axis.
Multiplication by $c$ reflects it upon the line $x-y=0$.
Multiplication by $sc$ turns it forward $\pi/2$.
Multiplication by $cs$ turns it backward $\pi/2$.
Multiplication by $scs$ reflects it upon the line $x+y=0$.
Multiplication by $csc$ reflects it upon the $x$-axis.
Multiplication by $(sc)^2$ turns it forward or backward $\pi$.

Of course a reflection on a line followed by a reflection on that line, or a turn forward followed by an equal turn backward simply leaves alone; is equivalent to unity.

Reflection on a line can be replaced by a half-turn about that line as an axis. If now we perform the operations, thus modified, upon a square, whose center is the origen and whose sides are parallel to the coordinate axes, they will each bring the square into coincidence with itself. Thus the group and the square "belong to each other," as also do the group and a set of eight angles all having numerically equivalent sets of trigonometric functions.

The group has various subgroups, viz.—

1. Those of order 2 generated by any self-reciprocal operation.
2. The group of order 4 generated by *sc* or *cs*.
3. The groups of order 4 generated geometrically by a half-turn about a line and a half-turn about a perpendicular thereto.

I write these all out—

1. $\{1, s\}$, $\{1, c\}$, $\{1, scs\}$, $\{1, csc\}$, $\{1, (sc)^2\}$.
2. $\{1, sc, cs, (sc)^2\}$.
3. $\{1, s, csc, (sc)^2\}$, $\{1, c, scs, (sc)^2\}$.

The operations 1, other than unity, are half-turns about an axis and leave unchanged all figures having two-fold symmetry about that axis; for example, a figure whose sections normal to the axis are parallelograms with centers in the axis.

The operations 2 leave unchanged all figures having four-fold symmetry about the $z$-axis through $O$ normal to the $xy$-plane. Such would be a regular four-sided pyramid whose axis was the $z$-axis.

The operations 3 leave unchanged figures having two-fold symmetry as to the $x$, $y$, and $z$-axes; for example a tetrahedron centered in $O$, whose three pairs of opposite edges are each pair perpendicular to one of the three axes while equally inclined to one and therefore both of the other axes.

Instead of operations upon an angle $\alpha$ we can have operations upon the expression $\cos\alpha + i\sin\alpha$ where $i$, as usual, denotes $\sqrt{-1}$. Then $s$ performed upon $\alpha$ in $\cos\alpha + i\sin\alpha$ gives

$$\cos(s\alpha) + i\sin(s\alpha) = \frac{-1}{\cos\alpha + i\sin\alpha},$$

while $c$ upon $\cos\alpha + i\sin\alpha$ gives

$$\cos(c\alpha) + i\sin(c\alpha) = \frac{i}{\cos\alpha + i\sin\alpha},$$

Thus, if $r$ means reciprocal-of, the group

$$\{1,\ s,\ c,\ sc,\ cs,\ scs,\ csc,\ (sc)^2\}$$

corresponds, operation by operation, to

$$\{1,\ -r,\ ir,\ i,\ -i,\ -ir,\ r,\ -1\}.$$

Note that $i$ and $r$ here stand for the *operations* multiplying-by $\sqrt{-1}$ and taking-reciprocal-of, so that $ir = -ri$. If we pass to the Argand diagram, by representing $x+iy$ by $(x, y)$, then multiplication by $i$ will turn through a right-angle, while $r$ will reflect on the $x$-axis. We thus reproduce our former geometry.

For still another representation, let the square belonging to the group have vertices $a, b, c, d,$ in the quadrants I, II, III, IV respectively, and let us agree that $(abcd)$ as an operator means to change $a, b, c, d$ into $b, c, d, a,$ advancing cyclically the letters within the symbol. Then the corresponding group on the letters is

$$\{1,\ (ab)(cd),\ (bd),\ (dcba),\ (abcd),\ (ac),\ (ad)(bc),\ (ac)(bd)\}.$$

The reader will find it interesting to write out the various sub-groups of the above and compare with the corresponding groups of movements of the square.

Again, we might consider the mutations of the coordinates of a point $(x, y)$ on the terminal line of the angle $\alpha$. This would

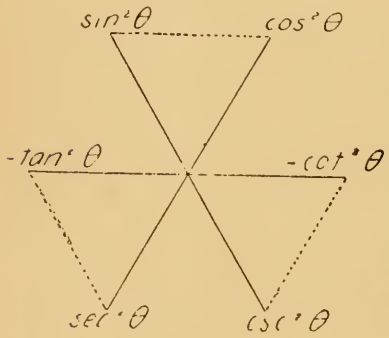
give the group generated by $(xy)(\bar{x}\bar{y})$ and $(x\bar{x})$ corresponding respectively to $c$ and $s$; the group, namely:

$$\{1, (xy)(\bar{x}\bar{y}), (xy\bar{x}\bar{y}), (x\bar{x}), (x\bar{x})(y\bar{y}), (x\bar{y})(\bar{x}y), (xy\bar{x}\bar{y}), (y\bar{y})\}.$$

There is, of course, a one-to-one correspondence between the operations of these various groups. We can best, indeed, regard the various groups as merely several out of many ways of writing the same group. It is the multiplication table, not the names we give the multipliers, that determines the character of the group.

The correspondence is exhibited below:

| $s$ | $c$ | $sc$ | $cs$ | $scs$ | $csc$ | $(sc)^2$ |
|---|---|---|---|---|---|---|
| $-r$ | $ir$ | $i$ | $-i$ | $-ir$ | $r$ | $-1$ |
| $(ab)(cd)$ | $(bd)$ | $(dcba)$ | $(abcd)$ | $(ac)$ | $(ad)(ba)$ | $(ac)(bd)$ |
| $(x\bar{x})$ | $(xy)(\bar{x}\bar{y})$ | $(x\bar{y}\bar{x}y)$ | $(xy\bar{x}\bar{y})$ | $(x\bar{y})(\bar{x}y)$ | $(y\bar{y})$ | $(x\bar{x})(y\bar{y})$ |




The six trigonometric functions are connected by a group somewhat similar to the one we have been studying. In the diagram to the left any pair of expressions joined by full lines are reciprocal; any pair of expressions joined by dotted lines have unity for their sum. It follows that, if $k^2$ be the value of any one of the expressions, the six are

$$k^2,\ 1-k^2,\ 1:k^2,\ k^2-1:k^2,\ 1:1-k^2,\ k^2:k^2-1.$$

If $r$ denote, as above, reciprocal-of, while $m$ denotes $1-$, the six may be written

$$k^2,\ mk^2,\ rk^2,\ mrk^2,\ rmk^2,\ mrmk^2,$$

giving the group $\{1, m, r, mr, rm, mrm\}$,

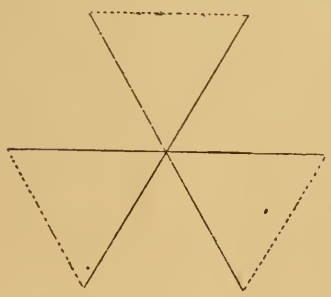
with the multiplication table—

| | 1 | $m$ | $r$ | $mr$ | $rm$ | $mrm$ |
|---|---|---|---|---|---|---|
| 1 | 1 | $m$ | $r$ | $mr$ | $rm$ | $mrm$ |
| $m$ | $m$ | 1 | $mr$ | $r$ | $mrm$ | $rm$ |
| $r$ | $r$ | $rm$ | 1 | $mrm$ | $m$ | $mr$ |
| $mr$ | $mr$ | $mrm$ | $m$ | $rm$ | 1 | $r$ |
| $rm$ | $rm$ | $r$ | $mrm$ | 1 | $mr$ | $m$ |
| $mrm$ | $mrm$ | $mr$ | $rm$ | $m$ | $r$ | 1 |

The subgroups are—

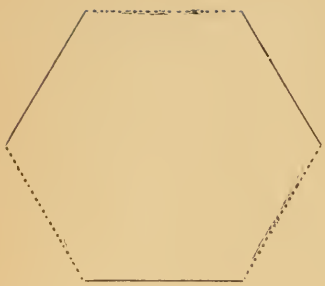
$$\{1, m\}, \{1, r\}, \{1, mr, rm\}, \{1, mrm\}.$$

That these are the only subgroups is easily seen; for either $m$, $r$, or $mrm$, together with any second operation of the group, will generate the entire group.



If, in the triply-crossed hexagon to the left, $f$ denotes motion from end to end of a full line, while $d$ denotes motion from end to end of a dotted one, it is plain that $d$ and $f$ generate a group differing from the previous one only in the substitution of $d$ for $m$ and $f$ for $r$. But the group fits precisely as well the uncrossed hexagon, just as the original group could have been entirely expressed in terms of $mrm$ and $m$ instead of $r$ and $m$.*

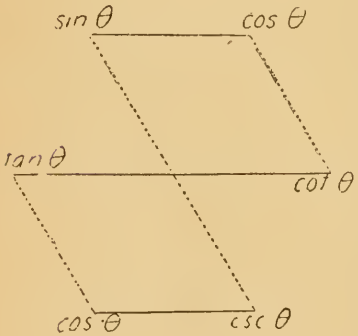
*If $n$ denotes $mrm$, the multiplication table in terms of $n$ and $m$ will come from that in terms of $r$ and $m$ by the mere replacement of $r$ by $n$.



Suppose the uncrossed hexagon regular and prolong the dotted sides to form an equilateral triangle. Consider now the movements that bring the figure into coincidence with itself. These are: turning the figure over about any altitude, and turning the figure in its own plane through one-third, two-thirds, or a whole revolution about its center. We thus have a group of rotations corresponding uniquely to the groups just considered. To see this, it is only necessary to let say $t_1$ and $t_2$ denote turning over about any two altitudes, when the multiplication table will be reproduced with $t_1$ and $t_2$ in place of $m$ and $r$. Thus the group we are now considering is related to the equilateral triangle precisely as was the one we started out with to the square.

If the corners of the triangle are marked $x$, $y$, $r$, and if $t_1$ causes an interchange of $x$ and $y$, while $t_2$ causes an interchange of $y$ and $r$, then $t_1$, $t_2$, and their combinations can be expressed in terms $x$, $y$, and $r$ as below.—

$$1,\quad t_1,\quad t_2,\quad t_1t_2,\quad t_2t_1,\quad t_1t_2t_1,$$
$$1,\ (xy),\ (yr),\ (xyr),\ (xry),\ (xr).$$




But if $x$ and $y$ denote rectangular coordinates of a point while $r$ and $\theta$ are polar coordinates of the same point, $(xy)$ changes each trigonometric function of $\theta$ into its complementary function, each function on the diagram to that joined to it by full lines; while $(yr)$ changes each into the one joined to it by dotted lines. The group $\{d, f\}$ fits this scheme quite as well as the one for which it was devised. The hexagon formed by the lines is now singly-crossed instead of triply-crossed or quite uncrossed, but, as in those, dotted lines alternate with full.

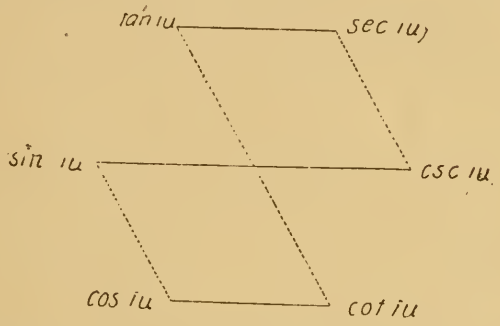
It is interesting to note the trigonometric meaning of the transformations $(xr)$ and $(yr)$. Connected with every number $\theta$ there is a number $u$, such that

$$\sin\theta = \tan iu.*$$

We call $\theta$ the Gudermanian of $u$, writing

$$\theta = gud\, u = \sin^{-1}\tan iu.$$

Expressed in terms of $u$ and like-placed on the hexagon with their equals in terms of $\theta$, the six functions are

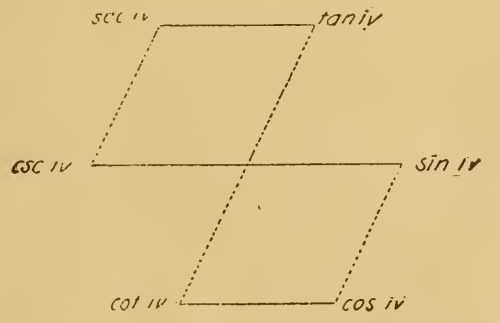



It thus appears that $(yr)$ changes each function of $iu$ into its complementary function.

Similarly, if we write

$$co\text{-}\theta = gud\, v$$

the six functions become




*$i$ is, as usual, $\sqrt{-1}$.

and it is thus the functions of $iv$ that are changed into their complementary functions by the transformation $(xr)$.

Therefore to each geometric operation of turning over about the altitude of an equilateral triangle corresponds the analytic operation of taking a complement. Likewise to the geometric operation of turning through $2\pi/3$ about an axis normal to the triangle and through its center, corresponds the analytic operation of taking complements as to two arguments in succession from the trio $\theta$, $iu$, $iv$.

Both the group of order 8 and that of order 6 are subgroups of a group of order 24. This latter group is connected with the elliptic functions in a manner which we proceed to explain.

In the theory of pendulum motion and elsewhere occurs the integral.

$$w=\int_0^{\phi}\frac{d\phi}{\sqrt{1-k^2\sin^2\phi}}$$

Here $\phi$ is called the *amplitude* of $w$ to the modulus $k$.

$$\phi=am(w,k,)=amw,$$
$$\sin\phi=\sin amw=snw,$$
$$\cos\phi=\cos amw=cnw,$$
$$\sqrt{1-k^2\sin^2\phi}=\triangle\phi=\triangle amu=dnu.$$

Glaisher has used $nsw$, $ncw$, $ndw$ to denote the reciprocals of these functions, while $scw$, $cdw$, $dsw$, . . . mean respectively $snw/cnw$, $cnw/dnw$, . . .

It is to be noticed that if $k=0$, then

$$w=\phi,\ snw=\sin w=\sin\phi,\ cnw=\cos w=\cos\phi,$$
$$dnw=1;\ scw=\tan w=\tan\phi,\ \text{etc.}$$

If, however, $k=1$,

$$gud\ w=\phi,\ snw=\tan i\phi,\ cnw=dnw=\sec i\phi,\ \text{etc.}$$

If we have four real quantities, $\alpha$, $\beta$, $\gamma$, $\delta$, such that

$$\infty>\alpha>\beta>\gamma>\delta;$$

and if, moreover, we define $\phi$ and $k$ by

$$k^2=\frac{(\beta-\gamma)(\alpha-\delta)}{(\alpha-\gamma)(\beta-\delta)},\quad \sin^2\phi=\frac{\beta-\delta}{\alpha-\delta}\cdot\frac{x-\alpha}{x-\beta};$$

it follows that

$$w,\text{ or }\int_0^{\phi}\frac{d\phi}{\sqrt{1-k^2\sin^2\phi}},$$

$$=\frac{\sqrt{(\alpha-\gamma)(\beta-\delta)}}{2}\int_{\alpha}^{x}\frac{dx}{\sqrt{(x-\alpha)(x-\beta)(x-\gamma)(x-\delta)}}$$

$$=\text{say, } M\int_{\alpha}^{x}\frac{dx}{\sqrt{X}}.$$

If now we perform upon $\sin\phi$ the 24 possible changes in the arrangement, substitutions we call them, of the letters $\alpha$, $\beta$, $\gamma$, $\delta$ entering into its expression, it will pass over always into some constant multiple of one of the Glaisher functions.

The substitution group on the letters $\alpha$, $\beta$, $\gamma$, $\delta$ is

$$G_{24}=\left\{\begin{array}{l}1,\ (\alpha\beta),\ (\alpha\gamma),\ (\alpha\delta),\ (\beta\gamma),\ (\beta\delta),\ (\gamma\delta),\\ (\beta\gamma\delta),\ (\beta\delta\gamma),\ (\alpha\gamma\delta),\ (\alpha\delta\gamma),\ (\alpha\beta\delta),\ (\alpha\delta\beta),\ (\alpha\beta\gamma),\ (\alpha\gamma\beta)\\ (\alpha\beta)(\gamma\delta),\ (\alpha\gamma)(\beta\delta),\ (\alpha\delta)(\beta\gamma)\\ (\alpha\beta\gamma\delta),\ (\alpha\delta\gamma\beta),\ (\alpha\gamma\beta\delta),\ (\alpha\delta\beta\gamma),\ (\alpha\beta\delta\gamma),\ (\alpha\gamma\delta\beta)\end{array}\right\}$$

Each substitution in the second line is the square of one next to it in that line. Each in the third line is the square of each of two in the fourth. Each in the fourth is the cube of one next to it in that line.

These 24 substitutions produce in $k^2$ only six changes, as follows:

$k^2=\text{say, } \sin^2\theta=\frac{\beta-\gamma}{\alpha-\gamma}\cdot\frac{\alpha-\delta}{\beta-\delta}$ is left unchanged by

$$1,\ (\alpha\beta)(\gamma\delta),\ (\alpha\gamma)(\beta\delta),\ (\alpha\delta)(\beta\gamma);$$

is changed to

$$k'^2=1-k^2=\cos^2\theta=\frac{\alpha-\beta}{\alpha-\gamma}\cdot\frac{\gamma-\delta}{\beta-\delta}\text{ by }(\alpha\gamma),\ (\beta\delta)(\alpha\beta\gamma\delta),\ (\alpha\delta\gamma\beta);$$

is changed to

$$\frac{1}{k^2}=csc^2\theta=\frac{\alpha-\gamma}{\beta-\gamma}\,\frac{\beta-\delta}{\alpha-\delta}\ \text{by}\ (\alpha\beta),\ (\gamma\delta),\ (\alpha\gamma\beta\delta),\ (\alpha\delta\beta\gamma);$$

is changed to

$$-\frac{k^2}{k'^2}=-tan^2\theta=-\frac{\beta-\gamma}{\alpha-\beta}\cdot\frac{\alpha-\delta}{\gamma-\delta}\ \text{by}\ (\alpha\delta),\ (\beta\gamma),\ (\alpha\beta\delta\gamma),\ (\alpha\gamma\delta\beta);$$

is changed to

$$\frac{1}{k'^2}=sec^2\theta=\frac{\alpha-\gamma}{\alpha-\beta}\cdot\frac{\beta-\delta}{\gamma-\delta}\ \text{by}\ (\alpha\delta\beta),\ (\beta\delta\gamma),\ (\alpha\beta\gamma),\ (\alpha\gamma\delta);$$

is changed to

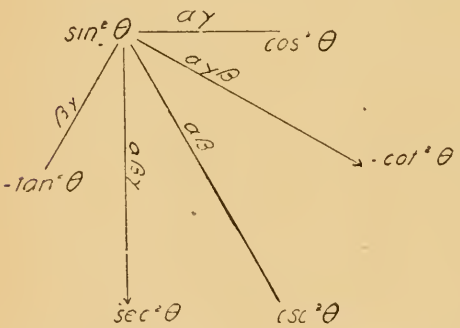
$$-\frac{k'^2}{k^2}=-cot^2\theta=-\frac{\alpha-\beta}{\beta-\gamma}\cdot\frac{\gamma-\delta}{\alpha-\delta}\ \text{by}\ (\alpha\beta\delta),\ (\beta\gamma\delta),\ (\alpha\gamma\beta),\ (\alpha\delta\gamma).$$

The substitutions from $G_{24}$ that leave unchanged some one letter, say $\delta$, form a subgroup of order 6, producing all the changes above recorded in $k^2$ or $sin^2\theta$. The group leaving out $\delta$ is

$$\{1,\ (\alpha\beta),\ (\alpha\gamma),\ (\beta\gamma),\ (\alpha\beta\gamma),\ (\alpha\gamma\beta)\}$$

and obviously the same as

$$\{1,\ (xy),\ (xz),\ (yz),\ (xyz),\ (xzy)\}.$$




To the left I have diagrammed the changes produced by the group in $\alpha$, $\beta$, $\gamma$. The arrow indicates that the change produced by the substitution is as the arrow flies, and not in the reverse way. In place of the substitutions written can be put, in this particular diagram, those which produce the same changes in $k^2$.

Consider now Glaisher's functions. We have—

$$sn^2w = \frac{\beta-\delta}{\alpha-\delta}\cdot\frac{x-\alpha}{x-\beta}, \qquad sin^2\theta sn^2w = \frac{\beta-\delta}{\alpha-\delta}\cdot\frac{x-\alpha}{x-\beta},$$

$$cn^2w = \frac{\alpha-\beta}{\alpha-\delta}\cdot\frac{x-\delta}{x-\beta}, \qquad tan^2\theta cn^2w = \frac{\beta-\gamma}{\gamma-\delta}\cdot\frac{x-\delta}{x-\beta},$$

$$dn^2w = \frac{\alpha-\beta}{\alpha-\gamma}\cdot\frac{x-\gamma}{x-\beta}, \qquad sec^2\theta dn^2w = \frac{\beta-\delta}{\gamma-\delta}\cdot\frac{x-\gamma}{x-\beta},$$

$$cd^2w = \frac{\alpha-\gamma}{\alpha-\delta}\cdot\frac{x-\delta}{x-\gamma}, \qquad sin^2\theta cd^2w = \frac{\beta-\gamma}{\beta-\delta}\cdot\frac{x-\delta}{x-\gamma},$$

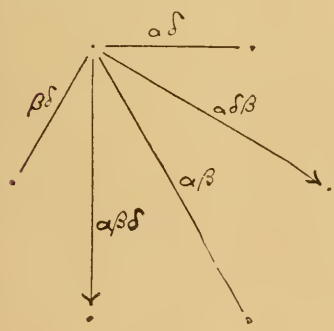
$$sec^2\theta ds^2w = \frac{\alpha-\beta}{\beta-\gamma}\cdot\frac{x-\gamma}{x-\alpha}, \qquad csc^2\theta ds^2w = \frac{\alpha-\delta}{\gamma-\delta}\cdot\frac{x-\gamma}{x-\alpha},$$

$$sc^2w = \frac{\beta-\delta}{\alpha-\beta}\cdot\frac{x-\alpha}{x-\delta}, \qquad cos^2\theta sc^2w = \frac{\gamma-\delta}{\alpha-\gamma}\cdot\frac{x-\alpha}{x-\delta},$$

together with twelve equations gotten by taking reciprocals of both members of each of these.

The set $\begin{matrix} sn^2w & cn^2w \\ -sc^2w & -cs^2w \\ nc^2w & ns^2w \end{matrix}$ is $\begin{matrix} sin^2\phi & cos^2\phi \\ -tan^2\phi & -cot^2\phi \\ sec^2\phi & csc^2\phi \end{matrix}$

and so of a sort frequently considered. The substitutions producing these changes are indicated to the left. Call any one of these forms $f_1(w, k) = f_1(w) = f_1$. Then any other substitution than that of the group in $\alpha$, $\beta$, $\delta$ will change any $f_1$ into a new form $f_2$ and the six forms $f_2$ will be related precisely as are the six forms $f_1$; for to operate upon $1-f_1$ or $1\div f_1$ with any substitutions is merely to operate upon the $f_1$ giving $1-f_2$ and $1\div f_2$. In particular, consider the three substitutions other than unity which leave $k^2$ unaltered, viz.: $(\alpha\delta)(\beta\gamma)$, $(\alpha\beta)(\gamma\delta)$, and $(\alpha\gamma)(\beta\delta)$. These belong to the rectangle whose corners are $\alpha$, $\beta$, $\gamma$, $\delta$ and may be symbolized by it.



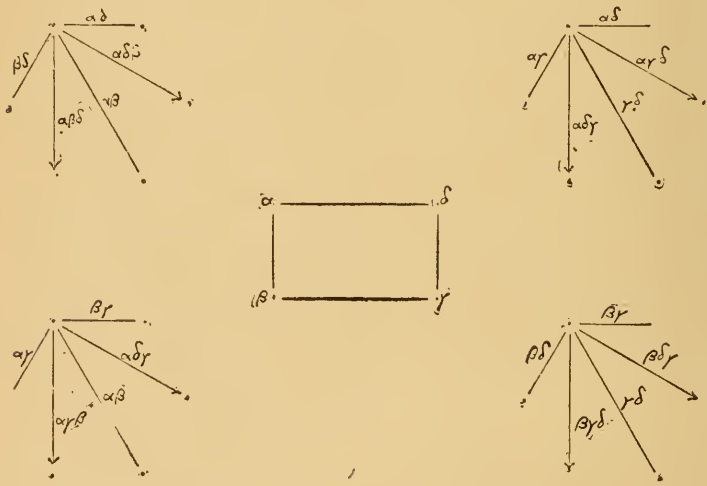
Let the first change $f_1$ to $f_2$ and $\therefore$ $f_2$ back to $f_1$, the second change $f_1$ to $f_3$, while the third changes $f_1$ to $f_4$.

We get—

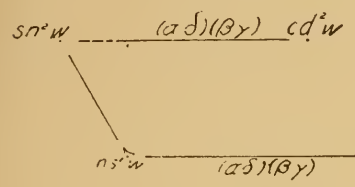
$$\begin{matrix} sn^2w & cn^2w \\ -sc^2w & \quad f_1 \quad & -cs^2w \\ nc^2w & ns^2w \end{matrix} \qquad \begin{matrix} cd^2w & cos^2\theta sd^2w \\ -sec^2\theta cs^2w & \quad f_2 \quad & -cos^2\theta sc^2w \\ sec^2\theta ds^2w & dc^2w \end{matrix}$$

$$\begin{matrix} csc^2\theta ns^2w & -csc^2\theta ds^2w \\ nd^2w & \quad f_3 \quad & dn^2w \\ -sin^2\theta sd^2w & sin^2\theta sn^2w \end{matrix} \qquad \begin{matrix} csc^2\theta dc^2w & -cot^2\theta nc^2w \\ sec^2\theta dn^2w & \quad f_4 \quad & cos^2\theta nd^2w \\ -tan^2\theta cn^2w & sin^2\theta cd^2w \end{matrix}$$

The substitutions connecting the forms in each set are shown below.



It will be noticed that we get the substitutions in any $f$ from those in any other by performing upon the symbols in the substitutions of the first $f$ the same substitution that carries the forms connected by the substitutions of the first $f$ into those connected by the substitutions of the second $f$. It is not difficult to see why this is. Consider for example the four forms to the left and their connections.




Plainly we can pass from $cd^2w$ to $dc^2w$ by the route $(\alpha\delta)(\beta\gamma).(\alpha\beta).(\alpha\delta)(\beta\gamma)$. But $(\alpha\delta)(\beta\gamma)$ changes $\delta$ and $\gamma$ to $\alpha$ and $\beta$ respectively; the second interchanges them as transformed; the third transforms them back again to $\delta$ and $\gamma$; so that it is the same as if $\delta$ and $\gamma$ had been interchanged.*

The substitutions of order 4 of which $(\alpha\beta\gamma\delta)$ is the type are not expressed in our scheme. They are all products of a substitution of order 2, within a set, by one of the substitutions that connects like-placed functions in the different sets. Thus—

$$(\alpha\beta\gamma\delta)=(\beta\delta).(\alpha\beta)(\gamma\delta)=(\alpha\beta)(\gamma\delta).(\alpha\gamma).$$

The five other pairs of equations similar to this can be obtained by merely permuting the letters $\alpha$, $\beta$, $\gamma$, $\delta$.

Similarly can we find the effect of any substitution not occurring in a set upon a form that does there occur.

E.g. $(\alpha\gamma)$ does not occur in the $f_1$ set.

But $(\alpha\gamma)=(\beta\delta).(\alpha\gamma)(\beta\delta)$

and $(\beta\delta)$ does occur in the set.

So $cn^2w(\alpha\gamma)=nc^2w.(\alpha\gamma)(\beta\delta)=-tan^2\theta cn^2w.$

Again, because $(\alpha\beta\gamma)=(\alpha\delta\beta).(\alpha\gamma)(\beta\delta),$

we have $cn^2w(\alpha\beta\gamma)=ns^2w.(\alpha\gamma)(\beta\delta)=sin^2\theta cd^2w.$

*It is usual to consider substitutions performed in the order in which they are written, i.e., from left to right.

The definite integrals

$$\int_0^{\pi/2} \frac{d\phi}{\sqrt{1-k^2\sin^2\phi}} \quad \text{and} \quad \int_0^{\pi/2} \frac{d\phi}{\sqrt{1-k'^2\sin^2\phi}}$$

are called $K$ and $K'$. Elliptic-function theory shows us that

$$sn^2(w+K)=cd^2w,\ sn^2(w+iK')=csc^2\theta ns^2w,$$
$$sn^2(w+K+iK')=csc^2\theta dc^2w,$$

with similar equations for the other forms. If, now, $f(w)$ denotes any one of the 24 forms,

$$f(w).(\alpha\delta)(\beta\gamma)=f(w+K), \quad \text{e.g. } f_1(w+K)=f_2(w),$$
$$f(w).(\alpha\beta)(\gamma\delta)=f(w+iK'), \quad \text{e.g. } f_3(w+iK')=f_1(w),$$
$$f(w).(\alpha\gamma)(\beta\delta)=f(w+K+iK'), \quad \text{e.g. } f_2(w+K+iK')=f_3(w).$$

When we wish to consider the functions dependent not only upon $w$ but also $k$ we write $f(w, k)$. Theory shows us that we can change to a reciprocal modulus by

$$k^2sn^2(w, k)=sn^2\left(kw, \frac{1}{k}\right),$$

or
$$\sin^2\theta sn^2(w, \sin\theta)=sn^2(w\sin\theta, \csc\theta)$$

i.e.
$$sn^2(w, \sin\theta)(\gamma\delta)=sn^2(w\sin\theta, \csc\theta),$$

or more generally $f_1(w, \sin\theta)(\gamma\delta)=f_1(w\sin\theta, \csc\theta)$,

and
$$f_3(w, \sin\theta)(\gamma\delta)=f_3(w\sin\theta, \csc\theta).$$

But also
$$cd^2\left(kw, \frac{1}{k}\right)=dc^2(w, k)=cd^2(w, k)(\gamma\delta),$$

whence
$$f_2(w\sin\theta, \csc\theta)=f_2(w, \sin\theta)(\gamma\delta);$$

while
$$\frac{1}{k^2}cd^2\left(w, \frac{1}{k}\right)=\frac{1}{k^2}dc^2(w, k)=[k^2cd^2(w, k)](\gamma\delta),$$

so that
$$f_4(w, \sin\theta)(\gamma\delta)=f_4(w\sin\theta, \csc\theta).$$

Thus the subscripts can be dropped and we can write

$$f(w, \sin\theta)(\gamma\delta)=f(w\sin\theta, \csc\theta),$$

or
$$f(w, k)(\gamma\delta)=f\left(kw, \frac{1}{k}\right).$$

We pass to a complementary modulus

by $sn^2(iw, k') = -sc^2(w, k)$ [analogous to $\sin^2\theta = -\tan^2 iu$]

whence $f_1(iw, k') = f_1(w).(\beta\delta)$;

by $dc^2(iw, k') = dn^2 w.(\beta\delta)$

whence $f_2(iw, k') = f_2(w, k).(\beta\delta)$

and $f_3(iw, k') = f_3(w, k).(\beta\delta)$;

finally by $csc^2\theta dc^2(iw, k') = sec^2\theta dc^2(w, k)$;

whence $f_4(iw, k') = f_4(w, k).(\beta\delta)$.

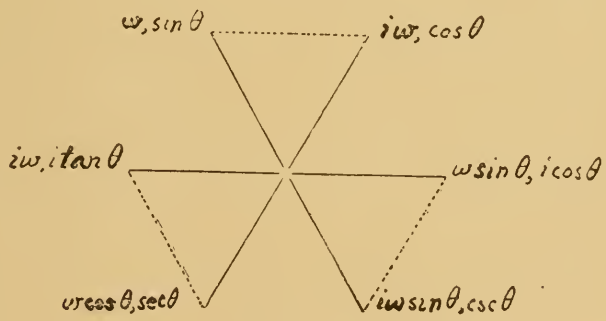
So that again the subscripts can be dropped and we can write

$$f(iw, k') = f(w, k).(\beta\delta)$$

or

$$f(iw, \cos\theta) = f(w, \sin\theta).(\beta\delta).$$

But the operations of passing to reciprocal and to complementary modulus generate a group. In writing the scheme of the group, only the arguments and the moduli are put at the corners of the hexagon. The dotted lines indicate $(\beta\gamma)$, the full lines $(\beta\delta)$.



## III.—*A New School of Jurists*

BY ROSCOE POUND

Hitherto it has been possible to divide jurists into three principal groups, according to their views of the nature of law and of the standpoint from which jurisprudence should be approached. We may call these groups the Philosophical School, the Historical School, and the Analytical School.[1] On closer analysis, the Philosophical School falls into two: the Eighteenth Century Law of Nature School, still represented by a Rousseauist school in France,[2] and a Later Philosophical School, of which there are numerous varieties.[3] The historical jurists may be distinguished into the German Historical School, whose method is philosophical and historical, and the English Historical School, whose method is comparative and historical. The Analytical School likewise has an older and a newer phase. The older type, which adheres to the analytical method exclusively,[4] may be distinguished from a later English school whose method is historical as well as analytical.[5] Thus it will be noted that there is a marked tendency to abandon the exclusive use of any one method, and to bring these formerly divergent schools into something like accord. In this movement, however, propinquity has hitherto played a curious part. The German Historical School arose

[1] On schools of jurists, reference may be made to Bluntschli, *Die neueren Rechtsschulen der deutschen Juristen;* Dahn, *Rechtsschulen*, in his *Rechtsphilosophische Studien*, 132; Dernburg, *Pandekten*, I, secs. 16, 17; Windscheid, *Pandekten*, I, secs. 7–10; Bryce, *Studies in History and Jurisprudence*, *Essay XII;* Pollock, *Oxford Lectures*, 1–36.

[2] Acollas, *L'Idée du Droit*, (10 ed.), 1889; *Introduction à l'étude du Droit*, 1885.

[3] Lorimer, *Institutes of Law*, 38; Ahrens, *Cours de Droit Naturel*, I, 26–80.

[4] *e.g.* Amos, *Systematic View of the Science of Jurisprudence*, 1872; Markby, *Elements of Law*, 1 ed., 1871; Holland, *Jurisprudence*, 1 ed., 1880.

[5] Perhaps Salmond (*Jurisprudence*, 1902) represents a philosophical type of what is still the analytical school.

in a country dominated by philosophical methods. Hence its methods are philosophical as well as historical. The English Historical School arose by way of revolt from a predominant analytical school. Hence its methods are comparative and historical, and the representatives of this school have regarded them as supplementary to analytical methods rather than as self-sufficient.[1] On the other hand, the influence of this revolt has given the recent analytical jurists a strong historical bent; while in Germany the rise of legislation, instead of creating an analytical school, has merely given an analytical turn to jurists who must still be counted either as philosophical or as historical. Moreover, the Philosophical School, except in Scotland and in Italy, its present stronghold, has almost turned historical.[2]

We should naturally expect a new school to emerge from this breakdown of the older schools, and there are many signs that such an event is in progress. Jurists are coming together upon a new ground from many different starting points. Some of them profess to find this new ground, potentially at least, in the schools from which they set out. But there is much to indicate that, instead of a further variation of one of the old creeds, an entirely new creed is to be looked for. The rising and still formative school, to which we must look henceforth for advance in juristic thought, may be styled the Sociological School.

The first movement in the new direction was from the then dominant historical school in Germany. The historical school began by applying historical method to the modern Roman law. Next we see a tendency to investigate the legal institutions of all Aryan peoples and reconstruct an Aryan *Urrecht*, in which the roots of modern law were to be found.[3] Presently, while the latter movement was in progress, the scope of inquiry was widened, an ethnological turn was given to historical jurisprudence, and the foundations of what Kohler styles universal legal history (*Universalrechtsgeschichte*) began to be laid. At first this wider historical jurisprudence was thought of as a com-

[1] Maine, *Ancient Law*, 7; Jenks, *Law and Politics in the Middle Ages*, 2.

[2] Prins, *La Philosophie du droit et l'école historique*, 8.

[3] The best examples are: Leist, *Altarisches Jus Gentium* (1889) and *Altarisches Jus Civile* (1892).

parative ethnological jurisprudence.[1] But it was not long in assuming the name and something of the character of a sociological jurisprudence,[2] and may be held one of the prime agencies in bringing about the new movement. The triumph of the Germanists, and consequent relegation of Roman law to a distinctly lower position in German legal education, began to be felt in turning the energies of jurists and scholars into wider fields of historical research, and a new type of legal literature, dealing with the legal institutions of all manner of peoples from the comparative and historical standpoints, grew to considerable proportions.[3] Even Romanists were affected, and deemed it necessary to begin a history of Roman law by an investigation of the legal institutions of Babylon.[4]

Meanwhile others were approaching the same position from the philosophical side. Dahn[5] in an article on the history and system of the philosophy of law, reprinted in 1883, clearly foreshadows the treatment of the conception of law now characteristic of the rising school. The latter define not law, but the legal order. He defines law, but defines it as an institution of society, and terms it a *Friedensordnung*. A little later, Nani,[6] writing in Italy, where the philosophical school is still paramount, rejected both the historical and the natural-law standpoints, and ranged himself with Dahn, declaring that comparative ethnology and anthropology must be the basis of jurisprudence. Wallaschek approached the analytical view. He asserted that the philosophy of law is "the science of juristic thought," and insisted that it was to be found in the actual methods of jurists.[7]

[1] Post, *Bausteine für eine algemeine Rechtswissenschaft* (1880), sec. 1.

[2] Post, *Grundlagen des Rechts* (1884). In this work there is an avowed attempt to put jurisprudence on a sociological basis.

[3] In addition to the numerous contributions of Kohler and Post, the newly published *Vorgeschichte des Rechts* of Willutzky (1903) may be mentioned.

[4] Ehrenberg, preface to Ihering, *Vorgeschichte der Indoeuropäer* (1894), vi.

[5] *Rechtsphilosophische Studien*, 119.

[6] *Vecchi e nuovi problemi del diritto* (1886).

[7] *Studien zur Rechtsphilosophie* (1889). Schuppe carries this even further. *Jahrbücher der Int. Vereinig. für vergleich. Rechtswissenschaft*, Jahrg. I, art. I.

Kohler,[1] professing to follow Hegel, developed and limited these ideas, so as to set off the philosophy of law from history and anthropology on the one hand and from analysis of matured systems of law on the other, and yet give it an intimate relation to each. According to him, its province is philosophical study of the evolutionary processes by which law is formed. Thus, in his view, historical and philosophical jurisprudence are merged in a sociological jurisprudence, and lose their identity.

In order to perceive the place which this formative school occupies in the history of jurisprudence, and the work which lies immediately before it, we must understand the history of the conception of law and of the schools which have developed and debated it. And, since the definition of law was long the battle-ground of jurisprudence, there is no method by which this history may be set forth more concisely and strikingly than by examining the formulas by which jurists have attempted to express their conceptions and set forth their conclusions.

A developed body of law is made up of two chief elements: The enacted or imperative element, which is the modern element and is tending to become predominant, and the traditional or habitual element,—the older or historical element upon which juristic speculation proceeds by interpretation and analogy. Corresponding to these two elements in the law, two distinct words, originally expressing two distinct ideas, are to be found in most languages spoken by peoples among whom law has reached any great development. The one set of words (*ius, Recht, droit, diritto*) has particular reference to the idea of right and justice, but is used to mean law in general. It is appropriate to periods in which law is formative or is expanding and developing through juridical speculation or some other non-imperative agency. The other set of words (*lex, Gesetz, loi, legge*) refers primarily to that which is enacted or set authoritatively, but tends to mean law as a whole. It is appropriate to periods of enacted law, and to periods in which the growing-point is in legislation. As now one and now the other of the elements of which law is made up

[1] *Rechtsphilosophie und Universalrechtsgeschichte*, in Holtzendorff, *Encyklopädie der Rechtswissenschaft* (6 ed.), 9 (1902).

has prevailed; now one and now the other name has come to be used for the whole. The classical period of Roman law was marked by juristic rather than by legislative activity, and the classical period of the modern Roman law was similarly characterized. Hence the predominance of *ius* and its equivalents in the languages of continental Europe. On the other hand, in England, where a strong central authority took the administration of justice in hand from an early period, and the executive legislation of the royal writs created a vigorous system which attained fixity before juristic speculation was sufficiently advanced to exert an influence, *law*, a word of the second type, became the general term, and *right* never acquired more than an ethical signification. A similar double series is to be observed in the formulas in which jurists have expressed their conceptions of law. The two sets of words of which *ius* and *lex* respectively are the types represent two ideas between which definitions of law have oscillated according to the circumstances of legal systems and the agencies through which their rules have been expressed for the time being.

The first attempts at a formula which have come to us from a Roman jurist or philosopher are to be found in the writings of Cicero. Cicero lived in a transition period, that of the *ius gentium,* after the strict, formal law set down in the Twelve Tables had been modified profoundly by the praetor's edict, but before the period of the great jurisconsults. A period of enacted law had come to an end; one of juristic speculation was beginning. His formulas, accordingly, savor of each. His essay *De Legibus*, purporting to contain the discourse of a jurisconsult asked to expound his views of the *ius ciuile,*[1] is in name a dialogue on the *rules of law,* and he defines not *ius,* but *lex.* Yet he does not use *lex* in the stricter sense of a statute or enacted rule, as in Capito's well-known formula in the next generation,[2] but gives it the wider meaning of law. His formulas are doubtless drawn from or modeled upon Greek originals. Nevertheless, it is note-

[1] *De Legibus*, I, 4.

[2] "A *lex* is a general command of the people or of the *plebs*, upon question by the magistrate." *Aulus Gellius*, X, 20, 2.

worthy that, as he puts them, they have something of the idea of authority and command, appropriate to the period just past, and something of the idea of reason and justice, appropriate to the immediate future.[1]

Passing to the classical jurists, in the golden age of juristic law-making, we find the idea of authority and command has disappeared, and reason and justice, to which the jurists of the time were striving to make the actual rules of law conform, alone are insisted upon. Thus Celsus (beginning of the second century) and Ulpian, following him, define law (*ius*) as the "art of what is right and equitable,"[2] and the latter defines jurisprudence as "the science of the just and the unjust."[3] Paulus in like manner says law (*ius*) is "that which is always equitable and right."[4] By the middle of the third century, however, the period of the classical jurists is past. Rescripts of the emperor supplant *responsa* of the jurisconsults as the source of private law, and by the end of the fourth century these rescripts cease to be authoritative except for those to whom addressed. From the time of Diocletian (284), imperial legislation becomes the growing-point of the law. This period has left no juridical or philosophical treatise to set forth the current notion of law. But it can hardly be an accident that the word *lex* began to mean law in general during the period of legislation and codification from Diocletian to Justinian.[5] An antiquarian revival in the reign of Justinian preserved for us the formulas of the classical jurists. But the Institutes and Digest give us the legal speculation of the

[1] "Law (*lex*) is the right reason of commanding and prohibiting." *De Legibus*, I, 5. "A just sanction, commanding what is upright and prohibiting the contrary." *Philipp.*, XI, 12.

[2] *Ars aequi et boni*, Dig., I, 1, 1, sec. 1.

[3] Dig., I, 1, 10, sec. 2.

[4] Dig., I, 1, 11, pr.

[5] Savigny, *Geschichte des Römischen Rechts im Mittelalter*, I, sec. 37. The first case of its use in this sense is in the *Lex Dei siue Mosaicorum et Romanorum Legum Collatio*, dating from the end of the fourth century. In this connection it is of interest to note that while *Recht*, *droit*, *diritto*, all meaning etymologically that which is straight or right, are equivalents of *ius* and are generic terms, and *Gesetz*, *loi*, and *legge*, equivalents of *lex*, are properly employed to mean enactment, legislation, or rule, yet *loi* and *legge*, for the same reasons that led to the wider meaning of *lex*, are sometimes used for law in the wider sense.

second century, not of the sixth. The ideas of an age when Roman law was known as a body of enactments are well illustrated by the definitions in the treatise on the etymology of words of Isidorus Hispalensis (ob. 636). He says: "*Fas* is divine law (*lex*), *ius* is human law. *Lex* is a written enactment. Custom is usage approved by time or unwritten law (*lex*) . . . . Usage, moreover, is a certain kind of law (*lex*) instituted by observance, which is held for enactment (*lex*) when enacted law is wanting."[1] In other words, enacted law is the normal type, customary law is a makeshift, to which men resort when the former fails them.[2] This view is even more apparent in the writings of the period prior to the rise of the school at Bologna. Although the classical formulas as to *ius* are repeated, they have become empty. *Lex* is the living word, and enactment is obviously felt to be the true law. For example, in the Expositio Terminorum, appended to the eleventh-century Petri Exceptiones Legum Romanorum, after Celsus's well-known formula, we come upon this: "Law (*lex*) is right (*ius*) enacted by wise princes."[3] Also in the related Libellus de Uerbis Legalibus: "But all law (*ius*) consists of statutes and customs. Statute (*lex*) is the enactment of princes written for the common good: custom is unwritten enactment (*lex*)."[4] The absence of any real line between *ius* and *lex*, so far as the former has more than an ethical meaning, is noteworthy.

In tracing the growth of the conception of law from the revival of legal studies at Bologna in the twelfth century to the time of Grotius, we must bear in mind that the theories of the time "implied the acceptance of three great authorities, which might be interpreted or applied, but were not to be questioned,—the authority of the Bible, of Aristotle, and of Justinian."[5] The

[1] Bruns, *Fontes Iuris Romani Antiqui*, II, 83.

[2] This was evidently an important point to insist upon in the period of the Leges Barbarorum. Thus in a capitulary of 793 (*Capit. Pippin. Reg. It.*, 23) we read: "Where law (*lex*) is wanting, let custom prevail, *and let no custom be put over the law.*"

[3] Compare this with Gaius, I, 2: "*Constant autem iura . . . ex legibus*," etc.

[4] Fitting, *Juristische Schriften des früheren Mittelalters*, 164, 181.

[5] Ritchie, *Natural Rights*, 7.

*Corpus Iuris Ciuilis,* as legislation of the emperor Justinian, was supposed to be binding statute law, and was properly to be designated *lex.* In this belief, jurists were engaged in interpreting and commenting upon the authoritative text, so as to fit it to the conditions of the modern world. As the reception of Roman law proceeded, the law in continental Europe was made up of the Corpus Juris with its modern gloss,—which, together with the legislation of contemporary sovereigns, was regarded as enacted law,—and the customary law of the various peoples, as it had developed prior to the revival or reception of the Roman law. Hence Gratian (about 1150), instead of drawing upon the classical definitions of *ius,* turns to the formulas of Isidorus Hispalensis, already quoted, and tells us, substantially in the latter's very words, that all *ius* consists of enactments and customs; that *lex* is a written enactment; and that custom is a certain kind of *ius* which is taken for *lex* when enacted law is wanting.[1] For him, too, enacted law was the normal type, and customary law a mere makeshift to which men resorted for want of enactment in order to prevent failure of justice. During this period English judges were constructing the common law of England by developing a judge-made customary law through interpretation and analogical extension of writs and precedents. English law was *ius,* not *lex,* although the powerful central authority behind it gave it the strength of imperative law and obscured the ethical and logical element, usually so prominent in non-legislative systems. But the title *De Legibus et Consuetudinibus,* borne both by Glanvill's treatise and by Bracton's, makes it evident that the continental ideas as to the nature of law were taken for granted. Indeed, Glanvill (about 1189) feels compelled to consider whether England has laws in view of the circumstance that the rules administered by the king's judges are not enacted.[2] The beginning of the movement back to the classical theory of law is to be seen in the next century, when St. Thomas Aquinas (1225 or 1227–74) formulates a theory which, in one way or another, has been felt in jurisprudence until very recent times. The Ger-

[1] CC. 2–5, Dist. 1.

[2] Preface (Beale's ed.), pp. xxviii–xxix.

manic principle that the state was bound to act by law coming in contact with the revived classical idea that the state exists of natural necessity for the general welfare, toward which law is but a means, so that the state creates law instead of merely recognizing it, led men to take up once more the distinction of natural law and positive law.[1] Positive law was the creature of the sovereign. But all sovereigns were subject to natural law, and their enactments in conflict therewith were simply void. Thomas Aquinas made over this philosophical theory to bring it into accord with theology. He divided the old *ius naturale* into two parts,—a *lex aeterna* and a *lex naturalis*,—of which the one is the "reason of the divine wisdom" governing the whole universe,[2] the other the law of human nature, proceeding ultimately from God but immediately from human reason, and governing the actions of men only. Man, he held, being a rational creature, participates in the eternal reason, so that the *must* which the *lex aeterna* addresses to the rest of creation is *ought* to him. Thus that part of the eternal law which man's reason reveals is to be called natural law.[3] While this scheme made law a body of enactments of the supreme law-giver of the universe, and so properly to be called *lex*, it took from positive law its character of enactment and made it a mere recognition of the *lex naturalis*, which was above all human authority. Hence it prepared the way for the more liberal notions of the humanist school of jurists and for the return in the seventeenth century to the classical conception of reasonableness as the source of authority in law. No conception has been more fruitful in legal history than this notion that the foundation of law is in ideal or natural justice.[4]

[1] Gierke, *Political Theories of the Middle Age*, 73, 74.

[2] *Summa Theologiae*, 1, 2, q. 93, art. 1.

[3] *Summa Theologiae*, 1, 2, q. 91, art. 2.

[4] The warfare which the historical and analytical schools have waged against the abstract systems which sometimes spring Minerva-like from the heads of metaphysical jurists has caused many to forget this. It is curious that a masterly sketch of legal evolution, such as Kohler's *Rechtsphil sophie und Universalrechtsgeschichte* (Holtzendorff, *Encyklopädie der Rechtswissenschaft*, 6 ed., 1–69), should pass over it so lightly. But see Grueber, *Einführung in die Rechtwissenschaft*, sec. 2 (Birkmeyer, *Encyklopädie der Rechtswissenschaft*, 15).

The influence of this theological-philosophical system of jurisprudence outlined by Thomas Aquinas may be seen in the formulas of practical lawyers down to the Reformation. To give but two examples: Fortescue (between 1453 and 1471), after defining *ius* in the words of the Digest, defines *lex,* used in the sense of positive law, as "a holy sanction (*sancio sancta*) commanding what is right and forbidding the contrary,"[1]—that is, a sanction added by the state to a rule of natural law. As this natural law, however, was discoverable by reason, the obvious effect of the doctrine was to require all rules of positive law to be tested by reason, and accordingly we find in Doctor and Student (before 1523) the significant statement that the law of nature "is called by them that be learned in the law of England the *law of reason.*"[2]

A new period begins with the great work of Grotius (1625). Although, perhaps, he did no more than give currency to what the expositors of natural law had worked out already,[3] the result of his book was to emancipate jurisprudence from theology.[4] Soon afterward Conring (1643) overthrew the notion of the statutory authority of the Corpus Juris.[5] Thus natural law ceased to be *lex naturalis,* the enactments of a supernatural legislator, and became once more *ius naturale,* the dictates of reason in view of the exigencies of human constitution and of human society. And positive law became the application of reason to the civil relations of men, whereof, on the Continent, the Corpus Juris was the chiefest exponent merely because of its inherent reasonableness.[6] Thus a movement arose comparable to the clas-

[1] *De Laudibus Legum Angliae*, cap. 3. This goes back to Cicero (*sanctio iusta, iubens honesta et prohibens contraria*). But the choice of this formula and the pious turn given it are remarkable. Compare Bracton, I, 3.

[2] *Doctor and Student.* Introduction.

[3] Hinrichs, *Geschichte der Rechts und Staatsprincipien seit der Reformation*, I, 59.

[4] Lioy, *Philosophy of Right* (Hastie's Tr.), I, 113.

[5] *De Origine Iuris Germanici.* See Brunner, *Gundzüge der Deutschen Rechtsgeschichte*, sec. 64; Stintzing, *Geschichte der Deutschen Rechtswissenschaft*, II, 3.

[6] "The grand destinies of Rome are not yet accomplished; she reigns throughout the world by her reason, after having ceased to reign by her authority." D'Aguesseau (1658–1751), quoted by Kent, *Commentaries*, I, 516.

sical period of Roman law, in which the growing-point was to be found in juristic speculation under the influence of a philosophical theory. Until the rise of legislation upon the Continent, the theory of natural law was dominant in jurisprudence. The idea which was at work in legal theory and practice can not be stated more clearly than in the words of Montesquieu (1748): "Law in general is human reason."[1] In the eighteenth century, the movement for codification and the influence of an age of absolute governments revived the older conception of law, natural and positive, as enactment, and brought about a reaction. This reaction begins, indeed, with Hobbes, a century earlier. Writing in England where there was a vigorous and efficient legislative, and where, for historical reasons, the notion of natural law was producing no practical results, it was natural that he should be impressed with the imperative element only. Accordingly, he says: "Civil law is to every subject those rules which the commonwealth hath commanded him . . . to make use of for the distinction of right and wrong; that is, of what is contrary and what is not contrary to the rule."[2] Until Kant, this insistence upon the imperative element becomes gradually more and more marked. Thus Burlamaqui (1747) defines law as "a rule prescribed by the sovereign of a society to his subjects."[3] Likewise Rousseau (1762), seeing in law "the conditions of civil association," and perceiving that these conditions were controlled by a highly centralized sovereign, whereas in his view the people are the sole legitimate sovereign, insists upon the imperative side. He says: "Law is the expression of the general will."[4] Finally, Blackstone (1765), characteristically reconciling the current philosophy with his common sense as a practical lawyer, by the simple process of stating the results to

[1] *L'esprit des Lois*, liv. I, chap. 3.

[2] *Leviathan*, chap. 26. As to the circumstances influencing Hobbes's conception of law, see Maine, *Early Hist. Inst.*, 395.

[3] *Principes du Droit Naturel*, par. I, chap. 8, sec. 2. The imperative theory is stated very clearly as to positive law by Wolff, *Institutiones Juris Naturae et Gentium*, sec. 1068 (1750).

[4] *Contrat Social*, liv. 2, chap. 6.

which they led respectively side by side without comment,[1] adapted a Ciceronian formula so as to make it include both of the current conceptions.[2] English thought continued in the course marked by Hobbes. But on the Continent another period was about to begin under the influence of Kant.

The problem which confronted Kant and those who followed him more immediately was the relation of law to liberty. On the one hand, we live in an age of legislation, in which there is and must be *external* restraint and coercion, in which a philosophy that sees only reason and ideal justice is not the philosophy of the law that is. On the other hand, we live in a democratic age, in which the arbitrary and authoritative must have some solid basis other than mere authority, and in which the individual demands the widest possible freedom of action. How were these two ideas, external restraint and individual freedom of action, to be reconciled? This question furnishes the clue to the formulas of philosophers and of jurists during the hegemony of the German historical school. Kant met it by formulating the judicial notion of justice,—the notion of an equal chance to all exactly as they are, with no artificial or extrinsic handicaps. He looked on restraint as a means and freedom as an end, so that there should be complete freedom of action except so far as restraint was needed to insure harmonious coexistence of the individual with his fellows according to a universal rule.[3] Savigny (1840), as a lawyer, turned this formula of right into one of law: "The rules whereby the invisible boundaries are determined, within which the existence and the activity of each individual gain secure and free opportunity."[4] Acollas (1885), in a country governed by a code and in an age of legislation, gives us a modern version: "The aggregate of the rules which pro-

[1] Compare his statement of the extreme view as to conflict of legislation and natural law (I, 43) with his statement as to the omnipotence of parliament (I, 161); his criticism of the state of nature theory (I, 47) with his scheme of rights based on that theory (I, 122); his curious juxtaposition of utilitarianism and Grotian natural law (I, 41).

[2] Commentaries, I, 44.

[3] *Metaphysische Anfangsgründe der Rechtslehre*, 27 (1797).

[4] *System des heutigen Römischen Rechts*, I, 52.

vide for the employment of the force of society to restrain those who infringe the liberty of others."[1] But after a time men became more doubtful of the efficacy of equality as a panacea, and the purely judicial idea of justice began to drop out of the formulas of metaphysical jurists. This appears noticeably in the writings of Krause and his school,[2] but may be seen also in recent formulas in which the imperative element is beginning to reappear.[3]

It will be noted that the modern formulas which have been cited are drawn from the philosophical standpoint. This is due to the influence of the historical school founded by Savigny. Regarding law as something organic, brought forth by inherent necessity and developed by natural forces, a product of the history of a people, he opposed codification and was skeptical as to the efficacy of legislation. Hence the imperative element plays no part in the conception of his school, and during the period of its predominance the best definitions are metaphysical. More recently the shifting of the growing point of German law to legislation has made itself felt in jurisprudence in a renewed insistence upon the imperative element. Ihering was the pioneer in this movement. He made the needed corrections in the theory based upon the imperative element and brought together the philosophical and the analytical conceptions, as Savigny had reconciled the philosophical with the historical.[4] After his discussion of the subject, the imperative element ceased to be kept in the background in German treatises.[5]

[1] *Introduction à l'étude du droit*, 2.

[2] "The organic whole of the external conditions of life measured by reason." Krause, *Abriss des Systemes der Philosophie des Rechtes*, 209 (1828).

[3] E.g., "An aggregate of rules which determine the mutual relations of men living in a community," Arndts, *Juristische Encyklopädie*, sec. 1 (1850); "The sum of the conditions of social co-existence with regard to the activity of the community and of individuals," Pulszky, *Theory of Law and Civil Society*, 312 (1888); "The sum of the rules which fix the relations of men living in society, or at least of the rules which are sanctioned by the society, imposed upon the individual by a social constraint," Brissaud, *Manuel d'histoire du droit Français*, 3 (1898).

[4] He defines law as: "The sum of the rules of constraint which obtain in a state." *Der Zweck im Recht*, I, 320 (1877).

[5] See Merkel, *Juristische Encyklopädie*, sec. 19; Gareis, *Rechtsencyklopädie*, sec. 5; Holtzendorff, *Encyklopädie der Rechtswissenschaft* (5 ed.), 5, 78; Sohm, *Institutes of Roman Law* (Tr. by Ledlie), 2 ed., 163.

While German jurists were coming back to the imperative idea, English jurists were engaged in getting away from it. The century from Blackstone to the Judicature Act was one of legislation. The growing-point of our law has been shifting slowly but surely to legislation for a long time. Nevertheless the dominant element is still case law, and common-law legislation is still very largely a mere outline, to be filled in by a judicial gloss. In consequence legislation has been so active that English jurists could not overlook the imperative element, and yet the other element has been too conspicuous to make it possible for an exclusively imperative theory to remain current. At the beginning of the reform-movement we find Bentham, the founder of the science of legislation, in a treatise on the principles of legislation, saying that "a law is either a command or the revocation of one."[1] His disciple Austin, writing when the reform-movement was in full career and was producing all manner of artificial changes, so that such parts of the law as remained in their original condition did so, as it were, by the grace of parliament, worked out this idea rigorously in all its consequences and founded his system upon it. The general and almost blind adherence to Austin's theories at one time, and the no less general and perhaps at times little less blind repudiation which has come by way of reaction, have obscured his true position in the history of jurisprudence. In many respects he marks the end of a period rather than a starting point. But the exactness and severity with which he summed up and restated what had long been the English theory of law made an issue on which the historical school could and did join. Blackstone had said already that law was a "rule of action which is prescribed by some superior, and which the inferior is bound to obey;" likewise, that it was a "rule of action dictated by some superior being."[2] But along with these statements Blackstone laid down, with no apparent thought of inconsistency, the most extreme views of Natural Law. Austin saw the inconsistency, and was never weary of pointing it out. Having to choose between the two ideas, in

[1] *Principles of Morals and Legislation*, 330 (1789).
[2] 1 *Comm.*, 38, 39.

view of the condition of law at the time, Austin naturally inclined to the imperative theory, and laid down its general principles almost in the very words of Blackstone. A law, in the most general sense, is, he says, "a rule laid down for the guidance of an intelligent being by an intelligent being having power over him."[1] Jurisprudence has to do with rules set by men to men, provided they are established by determinate political superiors.[2] He requires a state as a condition of positive law; for a law, being a command, must proceed from a determinate source and must be sanctioned.[3] Accordingly he defines positive law as "the aggregate of rules set by men as politically superior to men as politically subject."[4] This is simply a thorough carrying out of the notion we have traced from the beginnings of jurisprudence in the writings of jurists living in periods of legislative activity. Its defects are now well understood. Not only does it fail when applied to the law of archaic communities, but it requires an over-ingenious theory of implied command to account for the large traditional or customary element still to be found in developed systems. Nevertheless it must be admitted to represent what law is largely coming to be, especially where the common law itself is in force by the express terms of a statute.[5] The point most directly vulnerable is the notion that rules of law must be prescribed or *set* by the sovereign. We may understand such a doctrine when we find it still put forward by one who believes that rules of morals are to be taken from a spiritual sovereign and rules of law from a temporal sovereign.[6] We may expect to find it still asserted by those who cling to eighteenth century dogmas and refer the source of all things to some agreement or consent on the part of the "people."[7] But to one

[1] *Jurisprudence* (3 ed.), 88.

[2] *Ibid*, 89.

[3] *Idid.*, 90–94.

[4] *Ibid.*, 98, student's ed. (Campbell), 86.

[5] See, for instance, *Comp. Stat. Neb.*, chap. 15*a*. Compare Jenks, *Law and Politics in the Middle Ages*, 2; Rattigan, *Jurisprudence*, sec. 2; Brissaud, *Manuel d'histoire du droit Français*, 21.

[6] Vareilles-Sommières, *Principes fondamentaux de droit*, 12.

[7] "A rule agreed upon by the people, regulating the rights and duties of persons." Andrews, *American Law*, sec. 72. This *agreement* of the people

who investigates the actual facts of existing systems it is impossible. The will of the state, or, if one likes, the will of the people is not always expressed in imperative form. The state may be passive. It may suffer old practices to continue or may continue to protect or require them, without any express declaration on the subject. Rules of law are administered by the courts, and the courts have been established by the state. This does not mean, however, that the state has established or prescribed the rules. These considerations must have led in time to an overhauling of Austin's theories had nothing happened to bring them suddenly in question. But contact of English lawyers with a living body of archaic law in India gave England a historical school of jurists and hastened the result. Hence Holland (1880) made a distinct advance in substituting the idea of *enforcement* by the sovereign.[1] The next improvement was to limit the formula to those rules enforced in the administration of justice.[2] Finally, we owe to Salmond a suggestion which serves tersely to reconcile the analysis of modern systems with the facts of legal history. He defines law as "the rules *recognized* and acted on in courts of justice."[3] If we substitute *or* for *and,* we have a formula which accords also with the circumstances of archaic law, since before the rise of the state as the active agent in putting down private war, law is something *recognized* in the administration of justice; and it continues to be merely recognized until the state becomes strong enough to take it up and *enforce* it. International law to-day is a system recognized by states.

and Austin's *command* of the sovereign are the same; each exists, as to the traditional element of the law by implication only. The one author looks to an ultimate moral source, the other to the immediate practical source of the sanction upon which both have fixed their attention.

[1] "A general rule of external human action, enforced by a sovereign political authority." *Jurisprudence*, chap. 3.

[2] "The sum of the rules administered by courts of justice." Pollock and Maitland, *Hist. Eng. Law* (1 ed.), xxv (1895). "The sum of the rules of justice administered in a state and by its authority." Pollock, *First Book of Jurisprudence*, 17 (1896). Compare formulas of Thayer (4 *Harv. Law Rev.*, 153), Gray (6 *Harv. Law Rev.*, 24), and Dicey (*Law of the Constitution*, 23), which approach this phase of the analytical definition.

[3] *Jurisprudence*, sec. 5 (1902). Compare his earlier statement: "The aggregate of principles or rules recognized or acted on by the state in the administration of justice." *First Principles of Jurisprudence*, 77 (1893).

We may hardly say that its rules for the government of the relations of states with each other are enforced.

Thus it appears that the growth of legislation as the chief agency in law-making has emphasized the imperative element in all recent formulas. In England, as the historical school came last, jurists have been tempering ultra-imperative analytical formulas to bring them into accord with the results of historical research. In Germany, where the historical school came earlier and waged its war with philosophical rather than with analytical antagonists, metaphysical formulas have had to be made over to accord with the every-day experience of those who live under the jurisdiction of legislatures. Since Hobbes, English jurists have always given the imperative element great prominence, and continental jurists, almost without exception, are coming to insist upon it more and more. Even writers on ethics have been influenced by this modern predominance of enacted law.[1] In Italy alone the theory of natural law and its concomitant methods still flourish despite a code.[2] But, as we have seen, in the history of jurisprudence periods of legislation and codification, in which the imperative theory of law has been predominant, have always been periods of stagnation. The law has lived and grown through juristic activity under the influence of ideas of natural right and justice or of reasonableness, not force, as the ultimate source of authority. Hence, if there were no counter movement visible, we might well regard the well-marked swing of the pendulum toward the imperative side as an ill omen.[3] It is precisely here that the new Sociological School has its opportunity. Realizing that a final answer to the question, "What is law?" is impossible, since the thing to be defined is living and growing, and therefore subject to change, the most conspicuous representative of the new school abandons that question and goes behind

[1] "We must define Laws to be rules of conduct laid down by a Rightful Authority, commanding within the limits of its authority." Sidgwick, *Methods of Ethics* (6 ed.), 296.

[2] Lioy, *Philosophy of Right* (Hastie's Tr.), II, 379–392. But a decadence has been remarked. Carle, *Vita del diritto*, (2 ed.), sec. 204 (1890).

[3] A protest has appeared in Austria already. Ehrlich, *Freie Rechtsfindung und freie Rechtswissenschaft* (1903).

it to define the legal order (*Rechtsordnung*) in which law results and for which it exists.[1] The means of attaining this legal order may vary. They may be command and coercion or reason and justice. But the end has been before men from the beginning of legal evolution. By appealing from the particular phase of law which is now current to the universal conception of the legal order, the new school points out the road for future development in jurisprudence. Law is not an end, but a means. A school which studies it as a social mechanism[2] will do no little service if it but deliver us from the condition of dry rot which juristic thought has hitherto contracted in periods of enactment and codification, and preserve or restore the juristic ideals of reason and justice, which, for a time, we seem fated to lose or to forget.

[1] Kohler, *Einführung in die Rechtswissenschaft*, sec 1. cf. Paulsen, *Ethics* (Thilly's Tr.), 627. In Kohler we see the historical and the sociological views coming together; in Paulsen the teleological and the sociological.

[2] "A mechanism in the service of the good." Paulsen, l.c.

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# University Studies

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## I.—*The Causes of the Insurrection of the 5th and 6th of October, 1789*

BY JULIA CREWITT STODDARD

### INTRODUCTION

Many explanations have been offered by historians for the insurrection of the 5th and 6th of October, 1789, when a Parisian mob marched to Versailles and brought back the king to Paris. It has been claimed by some writers that the movement was the result of conspiracies, that it was brought about by individuals for motives of personal ambition; by others that "it was entirely unforeseen, spontaneous, and truly popular," that "the events of these two days are due to an extraordinary concatenation of fortuitous circumstances."[1]

It will be the purpose of this paper to find as much as possible of the truth or error in these various interpretations. By a study of the economic conditions of France, and by tracing the influence of a bad system of agriculture and a demoralized grain trade in producing a state of want and suffering, I shall endeavor to show that Paris was ripe for revolt. And if it does not appear that hunger was the only "real and certain cause" of the insur-

[1] Sybel, *History of the French Revolution*, I, 124, 131, 132; Stephens, *History of the French Revolution*, I, 220, 227; Loménie, *Les Mirabeau*, IV, 493; Blanc, *Histoire de la révolution française*, III, 44, 45, IV, 117, 118. See also Michelet, and Battifol cited by Mathiez.

rection, it will be seen that the fear of famine was a most important factor in that event.

The political situation will be studied; the interests and purposes of parties, and their effect on each other and on the course of events, will be pointed out. The evidence cited will, I think, create the conviction that there is no necessity for theories of deep-laid plots to account for this uprising.

Military complications will also be investigated and their influence on the course of events estimated. What was the attitude of the French guards and of the king's body-guard and what the effect of calling the regiment of Flanders?

The rôle played by individuals is not at all a simple question. But it is possible to show that this great movement was not the result of the political machinations of any one man or of any group of men, but that its causes were various and very complicated. Many things of different degrees of importance working together produced it. It will be my task to note these causes in their relations to each other and to what had gone before, to attempt to unravel the tangled web of circumstance, and to show the October days as a necessary link in the chain of historical development.

## I

### ECONOMIC CAUSES

Undoubtedly one of the causes of the revolt was scarcity of bread and fear of famine. How fundamental a cause this was it would be hard to understand without some examination of the economic conditions of France.

Taine has drawn so vivid a picture of the pitiful condition of the French peasant before the revolution that a study of the economic causes of any event in the course of that social upheaval seems incomplete without a rapid glance at his work.

It is well to remember that scarcity of food was no new thing in France: that for more than a hundred years poverty and wretchedness had burdened the whole rural population.[1] An

[1] Taine, *L'ancien régime*, 430, in a note: "L'oppression et la misère commencement vers 1672."

unequal and unjust system of taxation oppressed the needy farmers and exempted the wealthy and privileged classes. The manner of collecting taxes was most arbitrary. "The collectors with sheriffs' officers and locksmiths opened the doors, carried away the furniture and sold it for one-fourth of its value, so that the expense exceeded the *taille*."[1] Every evidence of increasing comfort, every acquisition which might indicate or even suggest prosperity was an excuse for the exaction of higher taxes. Even an appearance of physical improvement was a pretext for increasing assessment. D'Argenson is quoted by Taine to this effect: "An officer elect came into the village where my country home is situated and said that the *taille* for this year ought to be much increased in this parish, that he had noticed the peasants were much fatter than formerly, that he had seen chicken feathers on the door steps, indicating high living," etc.[2]

The only escape from intolerable extortions was the lowest possible degree of poverty. Frequently men were found living in wretched hovels totally unfit for human habitation. They were miserably clothed, sometimes in mere rags. Their only food was often black bread and water, when, indeed, they were not reduced to absolute starvation "eating grass like sheep and dying like flies."[3] After generations of this sort of life what wonder that French peasants were ignorant, suspicious, and stupid?[4]

Certainly many reforms had been instituted since the beginning of the reign of Louis XVI.[5] Attempts had been made to remedy the evils of unequal taxation. The *corvée*, a road tax worked out by the tenants and poorer farmers, had been suppressed in many parts of France, and a money tax on all proprietors alike substituted. The *taille* was modified to lessen the burdens of the poor. Nevertheless many of them still lived in misery too abject for human endurance. Arthur Young, who

[1] Taine, *L'ancien régime*, 433, quotation from D'Argenson.
[2] *Ibid.*, 434.
[3] *Ibid.*, 431.
[4] Young, *Travels in France*, 157.
[5] *Anciennes lois*, XXVIII, 358, 368.

spent three years in France collecting data for a work on agriculture, was "much impressed by the wretchedness of the country people."[1] "An Englishman," he says in his journal for July 12, 1789, "who has not traveled can not imagine the figure made by infinitely the greater part of the countrywomen of France; it speaks at first sight, hard and severe labor." Of one poor woman who complained to him of the hardships of their life, of oppressive feudal dues and heavy taxes crushing them down, he says: "This woman at no great distance might have been taken for sixty or seventy, her figure was so bent and her face so furrowed and hardened by labor, but she said she was only twenty-eight."[2]

There was a marked contrast between country and city. "What a miracle," exclaims Young, "that all this splendor and wealth of the cities of France should be so unconnected with the country! There are no gentle transitions from ease to comfort, from comfort to wealth; you pass at once from beggary to profusion, from misery in mud cabins to Mlle. Saint Huberti in splendid spectacles at 500 liv. a night. The country deserted, or if a gentleman is in it, you find him in some wretched hole to save that money which is lavished with such profusion in the luxuries of a capital."[3]

Was not this unfortunate state of affairs due in part to the state of agriculture in France? A study of Young leaves little doubt of it. There were great stretches of wild land. Young's journal for September, 1789 contains the following passages: At Nantes, "Mon Dieu, cried I to myself, do all the wastes, the deserts, the heath, ling, furz, broom and bog that I have passed through for 300 miles lead to this spectacle?"[4] At Frejus, "I passed to-day thirty miles of which five are not cultivated. The whole coast of Provence is nearly the same desert; yet the climate would give on all these mountains productions valuable for feeding sheep and cattle." And two days journey further on

[1] Young, *Travels in France*, 12, 83, 84, 88.
[2] *Ibid.*, 134.
[3] *Ibid.*, 89.
[4] *Ibid.*

he wrote, "The same bad country—not one mile in twenty cultivated."[1]

It thus appears that the area of cultivated land was too small to produce the necessary supply of foodstuffs. The extent of this area was unknown even to Necker, who was in a most favorable position to know and who in the preparation of his book, *De l'administration des finances,* certainly had occasion to inform himself upon this subject, if such a thing had been possible.[2] Various estimates had been made ranging from 40,000,000 to 112,760,000 acres, based for the most part on the amount of grain produced, a very manifest reason for wide differences between them. Out of eight estimates, two give 60,000,000 acres, while three are more and three less than this.[3]

According to Young's conjecture, the land under cultivation amounted to from 66,000,000 to 70,000,000 acres out of a total area of about 131,000,000.[4] The rest seems to have been utterly unimproved. When we consider that to-day only about 7½ per cent of the total area of France is unproductive, it is clear that one reason for scarcity of food was a failure to cultivate the land.

This growing neglect of the soil and desertion of the country did not go unheeded by the government. Measures had been taken which it was hoped would result in increasing the productive area. Necker states that in 1776 "the king remitted the *tailles* and the *vingtièmes* for twenty years to those who should bring land under cultivation."[5] It does not appear, however, that this measure was successful.[6] Again, a system of rotation of crops prevailed in the greater part of the realm by which land was left idle every third year, and by this arrangement the area under cultivation was reduced a fifth or even a fourth.[7]

[1] Young, *Travels in France*, 185.

[2] Necker, *De l'administration des finances*, III, 162.

[3] Young, *Travels in France*, 455.

[4] *Ibid.*, 456. Arable is the word used by Young, but it seems clear from the context that he meant to include all improved land.

[5] Necker, *De l'administration des finances*, III, 162.

[6] *Ibid.*, III, 164.

[7] Young, *Travels in France*, 456.

Not only was a large part of the arable land in France allowed to lie untilled, but the cultivated portion was so unskilfully managed as to reduce its productiveness to the minimum. Again and again Young groans over the poor husbandry.[1] At La Loge he says: "The fields are scenes of pitiful management, as the houses are of misery! yet all this country is highly improvable if they knew what to do with it."[2] In Bretagne he asserts that "the country has a savage aspect; husbandry not much further advanced, at least in skill, than among the Hurons."[3] In other places the state of agriculture was a "disgrace to France."[4] Lands that might without much trouble be made to produce an average of £2 5*s*. per acre, "if farmers could be induced to change their methods," brought in fact only an average of £1 8*s*.[5] It was estimated that the total product from the harvests of France was to that of England as 3 to 8.[6]

This lack of enterprise in agricultural pursuits was so general and the annual product of the land so insufficient in consequence that the government had been impelled to take measures to remedy the evil. In the hope of inducing an improvement of methods there had been instituted a society "for the encouragement of agriculture." It was hoped that this society would succeed in creating a new interest in the subject, and by promoting the adoption of improved methods, increase the production of the country. By a ruling of the king, dated May 30, 1788, the Royal Society of Agriculture was empowered to distribute prizes and award gold medals for such improvement as might fulfil the demands of this society.[7] We have already seen that this measure was without success. Too many circumstances tended to interfere with quiet rural pursuits.[8] New methods are not readily adopted by the ignorant and suspicious. Without doubt the fear

[1] Young, *Travels in France*, 13, 155, 489.
[2] *Ibid.*, 12.
[3] *Ibid.*, 83.
[4] *Ibid.*, 12, 13, 155.
[5] Young, *Travels in France*.
[6] Champion in *Histoire générale*, VIII, 17.
[7] *Anciennes lois*, XXVIII, 573, 578.
[8] Young, *Travels in France*, 545.

that the tax collectors alone would profit by any increased production had its effect. Moreover, the unsettled condition of the country, the restless expectation of change was not more conducive to a new interest in agriculture than to other settled industries.

Husbandry, then, was at a low ebb. The amount of breadstuff produced was inadequate. But beyond this there were other reasons for scarcity. Traditions, reaching back to the time when separate barbarian tribes contended for supremacy in this land, kept the provinces apart and assured a certain amount of local independence. All over France there were still maintained between the country districts frontier lines that proved formidable barriers to commerce. Merchandise sent from Bretagne to Provence, for instance, "was subjected to eight declarations and as many examinations, paid seven taxes and changed vehicles twice."[1] The roads, moreover, were often bad. Even the road to Troyes, one of the most important in the kingdom, was utterly impassable in winter on account of the ruts.[2] The fact that there were some magnificent highways in France was of little consequence to those who were unable to reach them over the wretched roadways intervening.

To make the domestic trade still more difficult there was a constantly varying system of weights and measures. "The society of agriculture pointed out, in 1790, considerable differences in the same city, in the same town, even in the same village."[3] All these things, local barriers, bad roads, and differing weights and measures prevented the excess produced in one part from going to another.

Decrees for the free circulation of grain had been passed,[4] but had not been executed. Two opposite theories were held with regard to trade: one, that it should be free, that all would go well if the law of supply and demand were allowed to operate; the other claimed that it was the duty of government to watch over

[1] Champion in *Histoire générale*, VIII, 23.

[2] *Ibid.*, VIII, 25.

[3] *Ibid.*, VIII, 24.

[4] *Anciennes lois*, XXVIII, 361; Necker, *De l'administration des finances*, III, 161.

the interests of the state and place restrictions on commerce when public interest seemed to demand such action. Turgot had been of the first school; Necker was of the last.

The summer of 1788, just before the beginning of Necker's second administration, was one of extraordinary dryness. The crop was almost a total failure.[1] Necker began by prohibiting, in the most absolute manner, the exportation of grain and by offering subsidies for importation.[2] As this decree failed of the desired effect, it was followed by another in November in which the places of sale were limited to markets, and all speculation was forbidden.[3] Then there came a winter of such unusual severity as had never been known in France since the beginning of history. "On the 31st of December, 1788, the Reaumur thermometer registered 18 degrees below freezing in Paris. Frosts began on the 24th of November, and the Seine was frozen from the 26th."[4] Prices continued to rise and the suffering from cold and scarcity was terrible.

The government then resorted to more severe measures. In April there came another decree by which government officers were commanded to find out just what quantity of grain was held within their provinces, and to compel the holders, whether farmers or merchants, to supply the markets. This was intended to discourage speculation, and to reassure those whom the high prices naturally made uneasy.[5] There was a clause in this decree which forbade the gathering of crowds and shouting in public, since such acts might lead to rioting. It is evident from this decree that such manifestations of disorder were not infrequent.

Not only was domestic trade controlled by government, but foreign commerce also suffered severely from government interference. The privilege of trading with foreign countries was granted or taken away at the discretion of the government.[6]

[1] *Histoire parlementaire*, I, 282.
[2] *Anciennes lois*, XXVIII, 663.
[3] *Ibid.*, XXVIII, 629.
[4] *Histoire parlementaire*, I, 283.
[5] *Anciennes lois*, XXVIII, 664.
[6] *Ibid.*, XXVIII, 361, 363.

Necker's idea was that it was the duty of the administration "to suspend this liberty in certain places, under certain circumstances, or even in a general way when information which it alone was in a position to obtain should prompt such an act of prudence."[1] In September, 1788, as has been stated, all exportation of grain was positively forbidden. This prohibition, although repeated by the national assembly, did not have the desired effect. In the following September the exportation of grain continued "with fearful activity."[2]

While forbidding exportation the government was making an effort to relieve the scarcity by importations. In November, 1788, subsidies were granted for importation of grain from America, and in January for grain coming from different parts of Europe.[3] In April this premium was doubled. In June Necker announced that he had ordered "immense cargoes of wheat to be bought up all over Europe,"[4] for it was found necessary for the administration itself to take up the matter of supplying the markets. Through the summer this was done by importing grain from foreign lands.[5] The supply of Paris depended entirely on purchases made outside the country.[6] Jefferson speaks of a quantity of flour and wheat imported from America.[7] The scarcity throughout the country continuing, Bailly advocated in the assembly the buying up of a supply for the winter in foreign parts.[8]

What was the result of this government interference with the grain trade? According to Young, the effect of Necker's measures was disastrous. "I have had some conversation," says Young in his journal for June 10, "with well-informed persons on this topic. They assure me the price is much higher than the

[1] Necker, *De l'administration des finances*, III, 159.
[2] *Le point du jour*, III, 1, 2.
[3] *Histoire parlementaire*, I, 283; *Anciennes lois*, XXVIII, 663.
[4] Young, *Travels in France*, 477.
[5] *Procès-verbal de l'assemblée des électeurs de la ville de Paris*, II, 258.
[6] Bailly, *Mémoires*, III, 422.
[7] Jefferson, *Memoir, Correspondence and Miscellanies*, III, 2.
[8] *Actes de la commune de Paris*, I, 355.

proportion of the crop demanded and there would have been no real scarcity if Mr. Necker would have let the corn trade alone: but his edicts of restrictions have operated to raise the price more than all other causes together."[1] On the publication of Necker's *mémoire,* announcing that he had ordered the importation of immense cargoes of wheat,[2] "the price rose in one week 30 per cent." "I was personal witness," says Young, "of the effect of this publication in many markets; instead of sinking the price it raised it directly and enormously."[3]

"Proclamations against exports, ordinances regulating sale, laws against monopolizers or boasts of imports from abroad, all these measures have the same tendency: they confirm . . . the apprehension of want."[4] This fear of want was the greatest aggravation to the social troubles, tending to produce the very condition dreaded by its effect on the circulation of grain. It is probably no exaggeration to say that "more persons died of famine in consequence of these measures than all the corn produced by them would feed in a year."[5]

That the high prices tempted to speculation is without doubt. The opportunity was too good to be neglected. Whether these speculations were as enormous as contemporaries believed it would be impossible to say. Notwithstanding the known integrity of Bailly, the fact that he was a stanch patriot and mayor of Paris, and that he had been the first president of the assembly, the Paris committee of subsistence of which he was chairman did not escape suspicion. Gouverneur Morris, out of patience with Lafayette for delays in arranging for the food supply for the army, casts aspersions on some members of this committee. They have, he presumes, "been casting about for ways to make money out of the present distress."[6]

Another deplorable effect of government interference was that by these measures of restriction on the grain trade, the trade

[1] Young, *Travels in France*, 104.
[2] *Ibid.*, 476.
[3] *Ibid.*, 477.
[4] *Ibid.*, 476.
[5] *Ibid.*, 479.
[6] Morris, *Diary and Letters*, I, 167.

itself was demoralized. Pillage grew so common that farmers and merchants kept their grain at home through fear that the convoys might be attacked. After some grain wagons had been seized at Orleans the farmers refused to take their produce to that city.[1] Even where the producers were willing to take their grain to market they were sometimes prevented from doing so by their neighbors, the inhabitants of their own province, who feared scarcity for themselves. "Sometimes loads of grain were stopped by municipalities and the grain not allowed to pass through."[2] "All the towns," says Duquesnoy, "take upon themselves the rights of petty sovereignty and stop the passage of grain through their territory."[3]

But if government restrictions disorganized the grain trade, caused higher prices, and increased scarcity, speculation, and suffering throughout France, the effect in Paris was even more unfortunate. On the 19th of June the national assembly had appointed a committee of thirty-two members to look into the causes of the high prices and to find a means of relieving the public distress.[4] It was through this committee that grain was imported. But the details of providing food for the city of Paris were left to the capital itself.[5] The chief burden fell on Bailly and made his position one of tremendous difficulty and danger. On the 29th of August the assembly decreed the free circulation of grain in the interior,[6] but the king's sanction was long in coming. He announced on the 18th of September that he would sanction the decree, but gave warning that "in the existing state of things it would be a lack of wisdom to have it too rigorously executed."[7] And he deferred the matter. It was only on the most urgent demands of the assembly that the decree received the royal sanction three days later. Such evident reluctance

[1] Gomel, *Histoire financière de l'assemblée constituante*, I, 355.

[2] *Ibid.*, I, 262.

[3] Duquesnoy, *Journal*, I, 393.

[4] *Procès verbal de l'assemblée nationale*, No. 2, 2; Duquesnoy, *Journal*, I, 110.

[5] Bailly, *Mémoires*, III, 422.

[6] *Procès-verbal de l'assemblée nationale*, No. 62, 3.

[7] *Ibid.*, No. 78.

caused suspicion of the king's good faith. Nor were the representatives of the commune of Paris ready to support Bailly in his efforts to relieve the scarcity. They opposed his influence and hindered his usefulness.[1] Under these circumstances, secret speculation going on among members of the committee, the king half-hearted, perhaps unwilling in his support, and the commune opposing his efforts, no wonder that Bailly cries out that he "led a most frightful life providing the supply of food for Paris."[2] "For two months," he says on the 19th of June, "we never had more grain than enough for one day."[3] The life of the inhabitants of Paris depended from day to day on the never-failing punctuality and the unremitting vigilance of the municipal committee in looking after the important details of securing a supply.[4]

As Paris and Versailles were alike dependent on government importations for provision, it happened on one occasion that the guard sent to escort the convoys to the latter place took more than their just share of the wagons. This left Paris in such desperate straits that Bailly, as soon as he heard of it, sent two of his associates to Versailles with instructions to insist on the immediate return of the wagons. They were to say that if those wagons were not at the market before morning, Bailly would call together the battalions and explain the matter to them. In which case, Bailly significantly remarked, "there was reason to believe that 30,000 men would go after them."[5] There was plenty of grain at the Paris market before morning.

Sometimes the grain received would be of inferior quality, and when people began to complain and show an ugly disposition toward the bakers, the committee was forced to explain that although the bread undoubtedly tasted bad, from damage which

[1] Bailly, *Mémoires*, II, passim.

[2] *Ibid.*, II, 269.

[3] *Ibid.*, II, 283.

[4] *Ibid.*, II, 290. "L'approvisionnement de nos subsistances était toujours si court dans ce moment que la vie des habitants de Paris dépendait chaque jour de l'exactitude des envois aux moulins de celle des meuniers à moudre à Paris. Il fallait des personnes expressiment chargées de surveiller tous ces objets."

[5] *Ibid.*, II, 289.

the grain received coming so far by water, yet it was harmlesss and must of necessity be eaten.[1]

What were some of the results of this condition of affairs? From the poverty-stricken country the people moved in a constant stream to the cities. Paris had been increasing her number of tramps and beggars for several years. In 1789 there were, it was said, 40,000 residents who had no right to be called citizens. The financial situation killed every enterprise. The fear of bankruptcy stopped the circulation or investment of capital. There was no money. Commerce was dead. Manufactories were closed, and a great army of unemployed fermented in Paris. This army had been greatly increased by servants of the emigrating nobility thrown out of employment. Since July an incredible number of passports had been issued, 20,000 according to the Venetian ambassador.[2] No doubt the greater number of these were used by persons seeking refuge in the country, as it was forbidden to leave Paris without a passport, but many went beyond the frontier.[3] Antonio Capello, who was ambassador from Venice in Paris at this time, speaks of this "multitude . . . who will become a burden through their misery if they do not become formidable by their violence."[4] The same fear is expressed in a letter from Bailly to Necker: "I can not describe to you, Monsieur, the astonishing number of unfortunates who besiege me. Paris is in a condition that makes one tremble, especially when one thinks what must be the result, the greater part of the workingmen of this great city reduced to a state of absolute inactivity, a condition of distress all the more frightful that it strikes the poorest class, the class most apt to become enflamed."[5]

The danger of the situation was heightened by the constant pillage of grain. Scarcity and high prices tempted to lawless seizures of grain on the road. In the country, as already stated,

[1] Bailly, *Mémoires*, II, 202.

[2] Capello, *Dispacci degli ambasciatori Veniti alla corte di Francia durante la rivoluzione*, 62.

[3] Gomel, *Histoire financière de l'assemblée constituant*, I, 363.

[4] Capello, *Dispacci degli ambasciatori Veniti alla corte di Francia durante la rivoluzione*, 63.

[5] *Histoire parlementaire*, IV, 186.

convoys of grain were often prevented from passing out of a province. Wagons loaded with wheat and flour were pillaged almost daily, first in one place and then in another.[1] On the 29th of July, Bailly complains of being exposed to the greatest danger by the pillage of a government convoy on the way from Rouen.[2] And again about a month later, the wagons were pillaged first by mobs on the road, and again by bakers in the suburbs of Paris.[3] Duquesnoy's journal for the 3d of October contains the statement that "The city of Rouen has just stopped the last convoy of subsistence destined for Paris. Everything is in the most frightful distress there."[4]

Since early spring France had been given up more and more to a spirit of lawlessness and revolution. Disturbances broke out on all sides so simultaneously that it appeared that a "vast number of criminals, without visible leaders, had agreed among themselves to commit the same excesses."[5] Young wrote on the 10th of June, "Accounts arrive every moment from the provinces of riots and disturbances."[6] And on the 21st of July, "The spirit of revolt has gone forth into various parts of the kingdom. The price of bread prepares for violence. At Lyons . . . commotions furious as at Paris. Dauphiné is in arms and Bretagne in absolute rebellion." The same night there occurred a riot in Strasbourg which Young himself witnessed.[7]

A report was spread all over France that an army of brigands was overrunning the country plundering and burning. There was no truth in the report, but many châteaux had been burnt and the peasants everywhere were terror-stricken. It was the "Great fear." Citizens in cities and workmen in the fields, on hearing that the brigands were coming, left their work and made haste to arm themselves to meet the foe.[8] On the 4th of August

[1] Gomel, *Histoire financière de l'assemblée constituante*, 289.
[2] Bailly, *Mémoires*, II, 171.
[3] *Ibid.*, II, 305.
[4] Duquesnoy, *Journal*, I, 393.
[5] Taine, *L'ancien régime*, 8, quotation from Montjoie.
[6] Young, *Travels in France*, 104.
[7] *Ibid.*, 141 ff.
[8] Bailly, *Mémoires*, II, 160, 161.

Young reports that rumor had increased the size of this army to 1,600. The people were quite surprised that he discredited the stories of brigands and attributed the destruction of châteaux to the peasants.[1]

Paris was in a continual state of fermentation. Laborers demanded work and tailors an increase of wages. Wig-makers made public protests, and domestics united in a demand that the Savoyards be sent away so there would be less competition. Women went in crowds to the Hôtel de Ville to complain of the bakers and demand that measures be taken to provide food for the city.[2] There were continual disturbances over bread.[3] Gatherings at the Palais Royal became more and more tumultuous, and Lafayette had much trouble in dispersing riotous mobs.

One of the most exasperating things about the whole situation was the fact that certain speculators were growing rich at the expense of the public distress. "For money men have adulterated the food of their brothers with a deadly mixture," says Camille Desmoulins, after having gone over various intrigues of speculators before the committee of investigation, "They have said, 'What matter to me the sufferings, the sorrow, the groanings of the poor provided I have money? What matter to me the hospitals filled with scurvy patients, if I have money? What matters it to me if a mother is in despair that she can give her children no bread, if I have money?' "[4]

Under the influence of such language as this, it is no wonder that for a long time there had been a great outcry against speculators and monopolists. Foulon, director of the war department under Broglie, had been especially execrated because of a prevalent report that he had said the people should be made to eat grass. He had been obliged to conceal himself, on the change of ministers, but was discovered and brought back to Paris on the 22d of July. So great was the popular fury against him

[1] Young, *Travels in France*, 151, 155.

[2] Bailly, *Mémoires*, II, 276, 277; *Révolutions de Paris*, No. 6, 15–17; *Revue historique*, LXVIII, 259.

[3] Bailly, *Mémoires*, II, 351.

[4] *Histoire parlementaire*, III, 5, quotation from Camille Desmoulins.

that it was impossible for the mayor and Lafayette to save him from the mob. He was taken from the Hôtel de Ville and barbarously executed; his body was dragged through the streets and his head carried about on a pike.[1] Berthier, intendant of Paris and son-in-law of Foulon, shared with him the odious reputation of wishing to profit by famishing the people. He, too, fell a victim to the infuriated mob, and was even more savagely executed than Foulon had been on the same day.[2]

By these summary acts of vengeance several men, grain merchants and others, who, by reason of their knowledge of the business were of service to Bailly and his associates, were frightened out of the country. In this way the difficulties of the situation were increased.[3]

Agitation over the scarcity of bread in Paris continued to increase. On the 21st of August it was found necessary to place sentinels to guard the bakeries and see that just distribution was made.[4] This state of things continued through the whole month of September. The people stood in line for hours waiting their turn to be served.[5] The *Deux Amis* thus describe the situation: "From four in the morning crowds of men, women and children besieged the bakers' shops. A loaf of bread purchased, or conquered with the money in hand, was, as it were, a victory. The unfortunate day laborer, sometimes obliged to struggle until four in the afternoon to obtain food for his family, lost the day's wages and, without being able to satisfy his hunger, found himself the next day without money and without strength."[6]

The quality of the bread when once acquired was also a source of bitter resentment. It is described as of a "blackish color, earthy taste, and disgusting odor."[7] Many people ate rice. The effect of all this was a sort of panic. Some struggled to get more than they needed for their daily consumption in order to

[1] *Procès-verbal des électeurs de Paris*, II, 300–16.
[2] *Ibid*, II, 316–25.
[3] Bailly, *Mémoires*, II, 136, 158.
[4] *Révolutions de Paris*, No. VI, 28, 29.
[5] *Revue historique*, LXVIII, 258.
[6] Deux amis de la liberté, *Histoire de la révolution de France*, III, 147.
[7] *Ibid.*, III, 148.

be prepared to ward off starvation for a little longer when the supply should fail. They hoarded up food secretly. One old woman living in a garret had hidden away sixteen big loaves of bread.[1]

There seemed to be some reason to fear the supply would fail. "The boat which brought flour from the mills of Corbeil, and which had come twice a day in the beginning of the revolution, later came but once a day and finally only in the morning of one day and the evening of the next." So it happened that on Monday morning, the 5th of October, there was almost a total lack of bread in the markets.[2]

And all this scarcity, the lack of bread after an abundant harvest, the obstacles to the circulation of grain, all this wretched misery, was believed by the people to have been wilfully brought about by the aristocrats.[3] The thought is monstrous, but it was a time when everybody believed in conspiracies.[4] And what more natural than that this people, crushed for centuries beneath a cruel despotism, should be suspicious of their old-time enemies when roused from the lethargy of hopelessness by the first breath of liberty?

The newspapers, moreover, publicly accused the aristocrats. According to the *Révolutions de Paris,* of September 30, they were saying among themselves that "popular rumors, riots, the lack of bread, sooner or later, will rouse the people; they will turn against the municipal officers, and the assemblies of the communes, and will believe them guilty, will hunt them down

[1] Bailly, *Mémoires*, II, 299.

[2] *Révolutions de Paris*, No. XIII, 9; Capello, *Dispacci degli ambasciatori Veniti*, 71.

[3] Bailly, *Mémoires*, II, 292. "Le rècolte se faisait et elle était belle;" Deux amis de la liberté, *Histoire de la révolution de France*, III, 148; *Révolutions de Paris*, No. XIII, 7, 9: "On regardait les obstacles des grains et farines, comme l'ouvrage des grands seigneurs propriétaires, laïques ou ecclésiastiques. Le défaut presque absolu des subsistances et la mauvaise qualité du peu de pain qu'on a distribué dans la matinée du lundi ont rendu palpable à tous les citoyens cette vérité qui avait beaucoup été répetée la veille; que s'il fallait se battre contre l'armée des conjures, il ne fallait pas attendre que la faim nous eut entirement énervée."

[4] Malouet, *Mémoires*, I, 311: "Je croyais comme tout le monde aux conjurations."

and annihilate them, and will end by demanding the ancient régime."[1]

Other publications did even more than Loustalot's to intensify suspicions and excite the people to violence. One of the most incendiary contains the following appeal: "Parisians, open! open at last your eyes! Rise! rise from your lethargy! The aristocrats surround you on all sides. They wish to put you in fetters, and you sleep! If you do not make haste to destroy them you will be a prey to servitude, to misery, to desolation! Wake! Rouse yourselves!"[2]

Another, a pamphlet not less potent to move to revolt, was called "When shall we have bread?" and this distressing cry is repeated as a refrain after every paragraph. "Why, citizens, do Lafayette, Bailly, and the leaders of the commune allow you to lack bread? Is it to grow fat on your substance? Why do these infamous rascals bring troops to surround Paris, Versailles, and the neighborhood with pikes and soldiers under pretext of guarding the king and the national assembly? These scoundrels believe that you have too much to eat. That is why they send for troops to consume what there is very quickly, and then to strangle you. And you sleep! When shall we have bread? In the midst of abundance we have no bread!"[3]

Such appeals did not go unheeded. There were many prophecies of a second revolution. Jefferson in a letter dated the 18th of September says: "The danger of famine here has not ceased with a plentiful harvest. A new and unskilful administration has not yet got into the way of bringing regular supplies to the capital. We are in danger of hourly insurrection for want of bread."[4] Capello, the Venetian ambassador, on the 14th of September, asserts most positively that the "present revolution necessitates another revolution," which can not be very far off, whether sooner or later "will depend on the impulse of circum-

[1] *Révolutions de Paris*, No. XII, 29.

[2] *Revue historique* LXVIII, 267, quotation from *Le Fouet national, les pourquoi du mois de septembre.*

[3] *Revue historique*, LXVIII, 266, 267.

[4] Jefferson, *Memoir, Correspondence and Miscellanies*, III, 35.

stances."[1] Loustalot in the issue of his paper for October 1, after hinting at an aristocratic confederation, and expressing alarm, says significantly: "A second access of revolution is necessary. Everything is preparing for it."[2]

From all these troubles the poorer class looked to the king for deliverance. Still attached to monarchical traditions, they "had faith in the all-powerfulness and goodness of the king and were convinced that the famine would be permanently removed only on the day when his majesty should dwell in their midst."[3] If the king were in Paris all would go well. On the way back from Versailles what was the cry of victory of the women? "My friends, we shall lack bread no longer, we are bringing back the baker, the baker's wife and the baker's boy."[4] "It is a great day for the good Parisians," writes Marat in his journal, "to possess at last their king; his presence will change the face of things; the poor people will no longer die of hunger."[5]

When a young girl went about Paris early on the morning of the 5th with a drum calling the women together—"bread" was her rallying cry,[6] and "bread" was the cry before the Hôtel de Ville.[7] Even in the national assembly, during that memorable night session when the deputies were trying to preserve a semblance of order by carrying on a discussion on criminal law, cries of "bread! bread!" interrupted the debate.[8]

On the 2d of October the commune of Paris had sent a deputation to the assembly with certain demands, one of which was that some certain means should be adopted by which the free

[1] Capello, *Dispacci degli ambasciatori Veniti*, 63: "Io dico con asseveranza l'attuale revoluzione necessita un altra rivoluzione."

[2] *Révolutions de Paris*, No. XII, 31: "Il n'y a plus de foyer patriotique, il faut un second acces de révolution; tout s'y prépare."

[3] *Revue historique*, LXIX, 54.

[4] Bailly, *Mémoires*, III, 119; Deux amis de la liberté, *Histoire de la révolution de France*, III, 241; 242.

[5] Marat, *L'ami du peuple*, 73; *Revue historique*, LXIX, 54.

[6] Deux amis de la liberté, *Histoire de la révolution de France*, III, 151.

[7] *Ibid.*, III, 162.

[8] *Courrier de Provence*, III, 255. Duquesnoy, *Journal*, I, 405: "Pendant cette discussion plusieurs voix sont élevées des galeries: Vos belles phrases ne nous donneront pas du pain. Du pain! du pain! Parlez du pain!"

circulation of grain in the interior of the realm might be assured.[1] This demand was renewed by the women. They wished to be assured of means of subsistence in the prospect of coming winter. And after the assembly had decreed a strict police to facilitate the transportation of wheat, and after they were furnished with the king's assurance that he would do all in his power in the matter, many of the women, together with their leader, Maillard, returned to Paris in the night of the 5th.[2] Loustalot gives the "lack of bread" as one of the motives for the insurrection.[3] Was he not right? Were not the conditions such that the outbreak was inevitable? Could this movement have taken place as the result of mere political intrigue? Would it have been possible except among a people driven to desperation by physical distress? The conclusion seems beyond question: a very certain, active, and potent cause of the insurrection of the 5th and 6th of October was fear of famine.

## II

### POLITICAL MOTIVES

Human motives are always mixed. It was not alone the lack of bread that sent the mob to Versailles. If economic conditions were conducive to insurrection, the political situation was not less liable to provoke the movement of October, 1789.

Up to this time the revolution had made three great strides. First on the 23d of June, when an attempt was made to annul all that had been done since the meeting of the estates general and to restore old conditions, the deputies of the third estate re-

[1] *Le point du jour*, No. XCVIII, 203. One of the demands by this deputation on the 6th of October was that "la commune de Paris suppliait le roi de faire communiquer, par ses ministres les états et les moyens de subsistance de la capitale, afin de rassurer la multitude sur les craints qui redoublent aux approaches d'hiver." *Actes de la commune de Paris*, II, 183.

[2] Bailly, *Mémoires*, III, 421. Deposition of Maillard: "Ensuite il fit lecture de cinq pièces relative à la démande . . . pour les subsistances . . . les pièces furent transcrites . . . et lui déposant immediatement après, revînt à Paris avec une partie de ces femmes." Also p. 118. "Maillard et son cortège avaient paru de grande matin a l'hôtel de ville"; Deux amis de la liberté, *Histoire de la révolution de France*, III, 206.

[3] *Révolutions de Paris*, No. XIII, 11.

fused to obey, and by insisting on their rights as representatives of the nation, took to themselves the sovereign power of the state. Second, on the 14th of July, when the monarchy seemed about to regain by force its ancient absolutism, the people of Paris rose, the Bastille fell, and victory was again with the popular cause. Finally, on the night of August 4, when discussion over the burning châteaux brought out the hatred of the feudal system, the national assembly, moved by an impulse of wild enthusiasm, passed decree after decree abolishing the rights and privileges of caste, and established a reign of equality before the law.

It was said that the revolution was over.[1] But a majority of the nobility and a minority of the clergy, including the highest dignitaries of the church, were not disposed to give up their ancient privileges without a struggle. Nor was the king himself favorable to such a sacrifice. Even in the last days of August, when the question of the royal veto came up for discussion in the assembly, the 4th of August decrees had not yet been sanctioned. Fears were naturally entertained that the veto, if granted to the king, might be used to defeat the will of the majority in the assembly and that its whole work might be overthrown. When at last the suspensive veto was passed it was with the distinct understanding that it should not be used to annul the decrees of the present assembly. A sentence in Barnave's letter to Mme. de Staël on the eve of the 10th of September, 1789, shows this clearly. "It is very important," he says, "that the letter (from Necker) which shall be read express the intention of the king not to use his suspensive right on the decrees of the present assembly, but only on laws which may be proposed by future assemblies. The interest which one part of the assembly takes in the decrees of the night of August 4 would be a great obstacle to the success of the proposition, if any doubt in this respect were allowed to subsist."[2] It was, therefore, only on this condition that the patriot deputies consented to the suspensive veto on September 11. It was naturally hoped that there would be no further delay about sanctioning and promulgating the decrees.

[1] Morris, *Diary and Letters*, I, 143.
[2] *Revue historique*, LXVII, 278.

But the message of Necker on the next day made no allusion to them.[1] Then the friends of the measure influenced the assembly to decide that the decrees of August 4 should be presented for royal sanction.[2] Two days later no answer had been received, and the matter was again agitated. Barnave urged the importance of the question in the following words: "I believe, gentlemen, that we ought to know what to maintain with respect to the decrees of August 4. Saturday it was said that they would be presented for sanction. But there is no law as to the form of presentation. It is not yet decided whether these decrees shall come under the suspensive veto, like laws made by other legislative bodies. It would be very troublesome if they should be stopped by the suspensive veto, because they have been published and the people everywhere have received them with transports of joy. I believe, therefore, that we ought to suspend the order of the day until we have voted on the question whether the decrees of August 4 shall be sanctioned purely and simply or whether they shall be submitted to the suspensive veto."[3]

Mirabeau went even further than Barnave: "The decrees of August 4," he said, "emanate from the constitutional power. . . . These decrees are not laws, and when you send them to the king, it is simply to have them promulgated, not sanctioned. . . . The decrees are for promulgation! Will the king refuse it? There is the question and I do not imagine that there can be any question about it."[4] The assembly took no action.

On the 18th of September the king sent a long *mémoire* in reply to the demand that he sanction the decrees of August 4, in which he expressed approval of some of these measures, found others very reasonable, and gave opinions more or less favorable on several more.[5] But this was not the unqualified sanction desired. The reading of the *mémoire* provoked much dissatisfac-

[1] *Letter et rapport de M. Necker*, Paris, 1789.

[2] *Procès-verbal de l'assemblée nationale*, LXXIII, 7; *Courrier de Provence*, No. XXII.

[3] *Histoir parlementaire*, II, 428.

[4] Méjan, *Collection complete des travaux de M. Mirabeau l'ainé*, II, 125.

[5] *Procès-verbal de l'assemblée nationale*, No. LXXVIII.

tion. It was claimed that the rights of the assembly relative to the constitution and the decrees of August 4 were beyond the power of the king's sanction or disapproval, and that all that had been demanded of him was the promulgation pure and simple. It was even proposed by Barnave to settle immediately the terms in which the sanction should be given, and to send the president to the king, to demand, without delay and during the session, the promulgation of the decrees of August 4.[1] The action of the king was regarded as a direct challenge to the assembly.[2] The discussion resulted in the adoption on the next day of the following motion: "The assembly decrees that the president go immediately to the king and implore him to order without delay the promulgation of the decrees of August 4 and the days following."[3]

The king's policy of procrastination would hardly serve him in the face of such determined persistence. He was not in a position to refuse absolutely, yet his reply on the following day was hardly more than a subterfuge. "He was going to order the publication of the decrees of August 4 in all his realm, but promulgation belonged only to laws already drawn up."[4]

What interpretation could be put on the king's action in this matter, if not that he intended to defer the promulgation of these decrees until he should be in a position to defeat altogether the wishes of the national assembly? And that such was indeed the case is proved by the evidence of his own words. On the 5th of August,[5] Louis XVI. wrote the following letter to the Archbishop of Arles: "I am pleased with this noble and generous proceeding of the first two orders of the state. They have made great sacrifices for the general reconciliation, for their country, for their king. . . The sacrifice is fine; but I can only admire it; I will never consent to despoil my clergy, my nobility . . .; I will not give my sanction to decrees which will despoil them, for then

[1] *Procès-verbal de l'assemblée nationale*, No. LXXVIII.
[2] Duquesnoy, *Journal*, I, 348.
[3] *Procès-verbal de l'assemblée nationale*, No. LXXIX.
[4] *Ibid.*, No. LXXX; Duquesnoy, *Journal*, I, 352.
[5] *Revue historique*, LXVII, 280.

the French people might some day accuse me of injustice or of weakness. Monsieur Archbishop, you submit yourself to the decrees of providence; I believe that I am submitting to providence in not yielding to this enthusiasm which has taken possession of all the orders, but which makes slight impression on my soul. I will do all in my power to preserve my clergy, my nobility. . . If force shall oblige me to sanction, then I will yield; but then there will be no longer in France either monarchy or monarch.[1]

In tracing the history of the 4th of August decrees, I have virtually shown the king's attitude towards the declaration of the rights of man and the constitutional articles proposed by the assembly. Since July the efforts of the friends of the revolution had been directed towards making a constitution in accordance with the wishes and demands of the people expressed in the *cahiers*. The plan of having a declaration of rights was proposed by Lafayette, who thus showed his admiration of the American declaration of independence.[2] This declaration together with the constitutional articles, having been discussed and voted upon by the assembly, was sent to the king for the royal sanction. The reply came at last on the 5th of October and raised a lively storm in the assembly. Instead of being a simple acceptance of the constitutional articles, it was a sort of criticism expressing approbation on some points and acceding to others only under the "positive condition," from which he "would never depart, that the executive power be left absolutely in the hands of the monarch." As for the declaration of rights, it contained "some very good maxims," but it also included principles susceptible of explanation and even of different interpretations."[3]

This reply, said Muguet in the assembly, "was not the response the nation had a right to expect."[4] If they granted that the king "had a right to modify the constitution, would they not be giving him the right to refuse it? If he could change it, could he not destroy it?" Robespierre claimed that "the response of

[1] *Histoire parlementaire*, II, 248.
[2] Lafayette, *Mémoires*, II. 360.
[3] *Procès-verbal de l'assemblée nationale*, No. XCII.
[4] *Histoire parlementaire*, III, 97.

the king was destructive not only of every constitution, but also of the national right to have a constitution. The constitutional articles were adopted only with a *positive condition:* he who could impose a condition on a constitution had the right to hinder the making of this constitution; he placed his will above the right of the nation." After a good deal of discussion the following decree was adopted: "The national assembly orders that the president, at the head of a delegation, go to-day to the king, to supplicate him to give his acceptance pure and simple to the articles of the declaration of rights, and to those of the constitution which have been presented to him."[1] At ten o'clock that same night, while Versailles was filled with the Parisian mob, Moumier, president of the assembly, read to the crowd of women and men who filled the square, the king's acceptance pure and simple of the constitutional articles and of the declaration of the rights of man.[2]

Why did Louis XVI. persist in opposing the will of the national representatives? He had been named the "Restorer of Liberty," and yet he was not ready to accept a parliamentary government. His letter to the archbishop shows a strong determination to maintain the privileges of rank. Superstitious piety led him to overlook the welfare of the whole nation in order to favor a class of priests. But instead of consistently upholding the aristocrats he refused to join their schemes of counter-revolution; he would not go to Metz and bring back the army to crush the revolution and restore the ancient régime.[3] Nor would he trust the moderates and accept their plan to transfer the court and assembly to some provincial town at a safe distance from Paris.[4] Neither had he any confidence in the ministers. Suspicious of others, yet too weak and incapable to comprehend and master the difficulties of his position for himself; possessing considerable courage and a high sense of honor, yet controlled by

[1] *Procès-verbal de l'assemblée nationale*, No. XCII.
[2] Deux amis de la liberté, *Histoire de la révolution de France*, III, 174.
[3] *Révolutions de Paris*, No. XIII, 18.
[4] Weber, *Mémoires*, I, 421; *Revue historique*, LXVII, 274.

his fears;[1] good, if goodness consists in kind intentions impossible of accomplishment; irresolute, yet possessed at times of a spirit of obstinacy only equaled by his incompetence; could France have had a greater misfortune at this critical period than the guidance of such a king? The ministers of Louis XVI. were no more competent to direct the course of events through such dangerous times than the king himself. Necker had followed a faint-hearted policy that contented nobody. The moderates and aristocrats were offended by his support of the suspensive veto, and the patriots by his action on the 4th of August decrees. The portrait of him drawn by Morris is pronounced by Mathiez "true to life."[2] "He is utterly ignorant of politics, by which I mean politics in the large sense, or that sublime science which embraces as its object the happiness of mankind. Consequently he neither knows what constitution to form nor how to obtain the consent of others to such as he wishes. From the moment of the convening of the states general, he has been afloat on the wide ocean of incidents. But what is most extraordinary is that M. Necker is a very poor financier. This I know will sound like heresy in the ears of most people, but it is true. The plans he has proposed are feeble and ineptious." The other ministers were no better. Montmorin a "mere clerk," Saint-Priest "a blunderer," La Tour du Pin lacking in energy, and the Archbishop of Bordeaux, to whom alone was conceded some intelligence, was said to use it only in intrigue."[3] And these were the official advisers of the king!

It has always been believed that Louis XVI. acted habitually under the influence of the queen or his counselors.[4] Marie Antoinette was a thorough aristocrat in her sympathies. The failure of counter-revolutionary intrigues had humiliated her. Necker's recall was an offense. Moreover she had no taste for government. But under the influence of Mercy, the Austrian

[1] Morris, *Diary and Letters*, I, 142.

[2] *Revue historique*, LXVII, 277; Morris, *Diary and Letters*, I, 283. See also Young's *Travels in France*, 108, 109, for the character of Necker.

[3] *Revue historique*, LXVII, 278.

[4] *Ibid.*, LXVII, 275.

ambassador, she had learned to interest herself in affairs of state.[1] For it was of the highest importance to Joseph II. that anarchy in France should cease. Austria's interest was in the preservation of the monarchy. "For this end the king and ministers should stand together against the usurpations of the assembly." So the queen was strongly urged by Joseph II. to sustain the recalled ministers. It is not likely that she forgot her humiliation, but she was made to feel the necessity of encouraging Necker and Montmorin in attempts of resistance to the revolution.[2] She was probably in sympathy with the courtiers who "had intentions from the beginning of September to apply to the army to dissolve the assembly." The royal governess received notice in September to be ready to leave at any time without preparation. This has been interpreted as showing the queen's hope of overcoming the king's resistance to flight.[3]

Marie Antoinette was too shallow to understand the signs of the times. The revolution was to her "but a transient crisis, a sort of Fronde which would end by dying out of itself." The assembly was but another states general that "would pass like all those which royalty had hitherto convoked, without having done anything except to make a little more noise and cause a little more fear."[4] Then the king would again become the absolute master.

That the queen was a prime mover in the Metz scheme[5] is evident from a letter written to her by D'Estaing. He had heard of the project from Lafayette and was much alarmed by the thought that it might get out. He says the Spanish ambassador "confessed to having heard from a reputable witness that the proposition had been made to sign an agreement." He points out the danger in such schemes and appeals to Marie Antoinette not to "follow a false course that would cause the shedding of blood," etc., etc.[6]

[1] *Revue historique*, LXVII, 276.
[2] *Ibid.*
[3] *Ibid.*, LXIX, 63.
[4] *Ibid*, LXVII, 275.
[5] Capello, *Dispacci degli ambasciatori Veniti*, 76.
[6] *L'ancien moniteur*, I, 521.

What wonder that the people hated and suspected her![1] The distrust which they had always felt for the "Austrian" increased in intensity. All sorts of wild rumors about her were current and were universally believed. "All the world knew the queen was conspiring against France in the most daring manner." Young heard a report on the 31st of July that Marie Antoinette had been "convicted of a plot to poison the king and monsieur and give the regency to the Count of Artois."[2] Two weeks later Young was himself arrested in Roya near Clermont on suspicion of being an "agent of the queen who intended to blow up the town with a mine and send all that escaped to the galleys." Commenting on this Young says: "That princess was so detested among the people that there seemed to be no absurdity too gross nor circumstances too impossible for their faith."[3]

Although much that was said of Marie Antoinette was without foundation, yet it is true that she was in touch with all that was going on about her, looking towards the restoration of the old order of things. The idea of defeating the revolution had never been given up. And there can be no doubt that the queen was in sympathy with the idea, or that she used her influence with the king to further the intrigues of the court party.

An example of this influence is seen in Necker's account of the preparations for the royal session in June. There had been several meetings and at last a council of state. The king and his ministers had agreed upon a plan and all seemed settled, when his majesty was suddenly called out. During his half-hour's absence the presumption was offered that they had "accomplished nothing," that "the queen alone would be permitted to interrupt a council of state;" that "the princes had apparently won her over," etc., etc.,[4] an interpretation which after-events showed to be only too correct.

[1] Capello, *Dispacci degli ambasciatori Venit.*, 75; Jefferson, *Memoir, Correspondence and Miscell nies*, III, 41.

[2] Young, *Travels in France*, 151.

[3] *Ibid.*, 162.

[4] Necker, *De la révolution française*, I, 286.

The success of the revolution meant the destruction of all class privileges and distinctions of rank. What more natural than that the great body of the aristocrats should contest openly or secretly, by every means in their power, each step in its progress? Their policy had been to block all measures of reform by systematic opposition or delay. It was publicly charged in the assembly on the 19th of September that "for fifteen days opposition to the clearest principles, and difficulties over the simplest questions had greatly increased."[1]

On the 22d of September the *Révolutions de Paris* published the following: "The municipal officers of Versailles have asked for 1000 soldiers. It is said these troops are to help the king to get away to Metz, and that he will return at the head of an army and try to enslave by right of conquest."[2] D'Estaing's letter to the queen has already been quoted. The plot of the aristocrats, to get the king to take refuge at Metz, to destroy the assembly, and to take by force the kingly power, now slipping from his grasp, was widely reported.[3] After the arrival of the regiment of Flanders, the "departure of the king, the dissolution of the assembly, and the success of civil war were spoken of no more mysteriously and in secret, but openly. It was pointed out how the army would increase, how a *Place d'armes* would be established at Metz where, in case of an improbable first defeat, there would be an impregnable asylum, and it would be easy to introduce foreign troops."[4]

After the October insurrection, charges against the aristocrats multiplied. The next number of the *Révolutions de Paris* contained the following: "The insolent aristocracy has been a second time thrown to the earth, and the nation has made one more step towards liberty. A few days ago we said *'A second* access of revolution is necessary, and everything is preparing for it.'

[1] *Courrier de Provence*, III, 108.

[2] *Révolutions de Paris*, No. XI, 24.

[3] Lafayette, *Mémoires*, II, 326, 329; Jefferson, *Memoir, Correspondence and Miscellanies*, III, 23; Deux amis de la liberté, *Histoire de la révolution de France*, III, 98, 99.

[4] Deux amis de la liberté, *Histoire de la révolution de France*, III, 120; *Révolutions de Paris*, No. XIII, 6.

Citizens were you not a few days ago on the eve of famine and of civil war? A prompt revolution, a moment of activity, a choice loudly expressed between death and liberty, stifled the conspiracy in its cradle."[1]

Capello, in his despatch for October 12 asserts that it "is published and reported that a counter-revolution was preparing to kill off the regular troops of Paris and to burn and sack a great many houses. Some suspected persons were imprisoned, and day before yesterday two men were arrested who were marking houses. Certainly a great number of houses were marked."[2]

It is not possible to determine the exact amount of truth in these reports. It seems most probable that fear of what the aristocrats might do, together with the knowledge of what they most certainly would like to do, caused much exaggeration. But it is beyond question that their interests were promoted by the action of the conservative deputies in the assembly.

The moderates were sincere patriots, but were alarmed at the reckless destruction of old customs and privileges on the night of August 4, and began to draw back. They were afraid that a revolution made in such haste would be neither legitimate nor secure. Although they saw the evils of feudalism, they were not blind to the dangers of anarchy. Mounier led the opposition against the suppression of feudal rights without indemnity. "These rights," he said, "have been bought and sold for centuries; it is in good faith that they have been placed on sale and have been made the foundation of several establishments; to annihilate them would be to annihilate contracts, ruin entire families, and overthrow the first foundations of public welfare."[3] Other deputies held the same opinions, some fearing to compromise the revolution by precipitous measures, others, less disinterested, because their income was affected by the decrees of August 4. They favored the English plan of having two houses, and would have given all necessary executive power to the monarch.[4] They de-

[1] *Révolutions de Paris*, No. XII, 1, 2.

[2] Capello, *Dispacci degli ambasciatori Veniti*, 75.

[3] *Revue historique*, LXVII, 264, 265.

[4] Lafayette, *Mémoires*, II, 299; Jefferson, *Memoir, Correspondence and Miscellanies*, III, 39.

fended the absolute veto, and this brought them near the court and ministerial parties and separated them from the patriots.[1] Towards the end of August, the breach between the conservatives and the popular party widened. Lafayette tried in vain to bring about a reconciliation.[2] The leaders of the left or patriot side "were ready to accept the absolute veto and the two chambers on three conditions: first, that the chamber of representatives could not be dissolved by the king; second, that the upper chamber have only a suspensive veto upon the decisions of the lower; third, that the national conventions be periodically charged with the revision of the constitution." But Mounier believed the majority of the assembly favored his views, and would make but one slight concession.[3] So the parties separated.

The fact that several presiding officers had been chosen from among the moderates was not conclusive evidence that the majority of the assembly agreed with them politically. According to Mathiez, the leaders were chosen for their eloquence and high moral character, and the majority "formed an undecided mass floating between the two parties, made up of good sincere men, passionately loving their country and profoundly attached to the public welfare." They voted against the veto "in spite of Mounier whom they esteemed and respected. In spite of him and in spite of Necker, in whom they had great confidence, they did not cease to demand the promulgation of the decrees of August 4." It was, therefore, "in vain that the moderate leaders had a connected policy—the majority on which they counted escaped them at the decisive moment."[4]

The discussion of the veto caused much public agitation.[5] Fears were entertained that the moderates had become corrupted by court influence. The August 4 decrees had not yet been sanctioned. The absolute veto would be a convenient weapon in

[1] Duquesnoy, *Journal*, I, 320.

[2] Lafayette, *Mémoires*, II, 298; Jefferson, *Memoir, Correspondence and Miscellanies*, III, 40.

[3] *Revue historique*, LXVII, 266, 267.

[4] *Ibid.*, LXVII, 269.

[5] Malouet, *Mémoires*, I, 367.

the hands of the aristocrats.[1] On the 30th of August a riot broke out at the Palais Royal.[2] It was said that "traitors wished the absolute veto; that France was about to be enslaved." It was proposed "that 15,000 men should march to Versailles to invite the nation to crush its unfaithful representatives and name others in their places and to supplicate the king to come to Paris for security. The Marquis of Saint Huruge was charged to carry this motion to the assembly."[3]

Mathiez draws a parallel between this insurrection and that of October. "The riot of August 30," he says, "like that of the 4th of October commenced by deputations to the commune. In both cases it was the queen who was the object of hatred and of most furious accusations. What is more remarkable, we find in the statement of the wishes of the insurgents of August the same thing that was demanded in October: that the king and his son be supplicated to come to the Louvre and to dwell there in the midst of his faithful Parisians."[4]

But if the thought of bringing the king to Paris appeared at this time, it was in no way the main or the general thought of the rioters. They wanted to punish the faithless conservative deputies for desertion to the ranks of the aristocrats.[5] The riot was soon crushed. At ten o'clock in the evening a message of warning had been sent to Versailles, but at two in the morning a second letter was sent "to inform you that in spite of the effervescence at the Palais Royal the precautions of the commandant have succeeded; all is quiet."[6]

In spite of this assurance that all was quiet the moderates had had too great a shock to recover at once from their fear. "If the insurrection should break out again and be successful—the assembly would be dispersed—and they would themselves lose their power, if not their lives. Even if a transfer of the court

[1] *Revue historique*, LXVII, 252.
[2] *Révolutions de Paris* No. VIII, 13.
[3] Bailly, *Mémoires*, II, 328.
[4] *Revue historique*, LXVII, 270.
[5] *Révolutions de Paris*, No. VIII, 13.
[6] *Histoire parlementaire*, II, 368.

and assembly to Paris should be all that was accomplished it would still put an end to the influence of the conservatives."[1] "On the 31st of August, while fears were still lively, Clermont-Tonnèrre proposed that in case of danger the national assembly quit Versailles and establish itself in another city far from the enterprises of the people of Paris."[2]

This proposition was afterwards adopted by the moderate party as the best means of assuring the independence of the assembly as well as preserving their own influence.[3] But they could not put their plan into execution without the help of the aristocrats, the ministers and the king. The aristocrats were already very desirous of getting the king away from Versailles and the neighborhood of Paris; their consent was not hard to win. At Soissons or at Compiègne their chances would be good for getting control of affairs with the help of the army.

As soon as the news reached Versailles of the threatened attack on the assembly, an understanding was reached between the leaders of the moderates and the representatives of the aristocrats. They agreed: "(1) That in view of the troubles and of the nearness of Paris the position of the king at Versailles was no longer tenable; (2) that the position of the assembly, threatened as it had been for some time in its principal members, was also untenable; (3) that whether the king should decide to leave Versailles or remain there, some body of troops of the line was absolutely necessary, conjointly with his guard, to preserve him from popular enterprises."[4]

A delegation was sent at once to the king to ask him that the assembly be transferred to Soissons or Compiègne.[5] His majesty had been hunting and was very tired. It was nevertheless thought necessary to hold a meeting of the council the same night. The result was totally unexpected, not only by the moderates and aristocrats but by the ministers themselves. The king

[1] *Revue historique*, LXVII, 270.
[2] *Ibid.*, LXVII, 271.
[3] *Ibid.*, LXVII, 272.
[4] Montlosier, *Mémoires*, I, 278; *Revue historique*, LXVII, 273.
[5] *Ibid.*, LXVII, 273.

slept or feigned sleep during the discussion of the matter and on awakening refused his consent to the proposed plan.[1] Whether this act was due to firmness and a fear of provoking an insurrection of the people by such open defiance, as Mathiez suggests,[2] or whether the king really slept in council, as seems quite probable in a man like him after a day in the open air, and on awakening gave his decision without definite knowledge of the plan or its advisers, the fact remains that he refused, to the consternation of all his counselors. And having given this answer, no power could make him retract. "In spite of the queen," it was said, "in spite of M. de Mercy, in spite of the most pressing insinuations of a great number of court nobles, the king decided to remain at Versailles."[3]

It is not to be imagined that the motives of all who supported the plan of removal to the provinces were equally disinterested. The moderates, while anxious to preserve their power in the assembly, were without doubt in favor of a representative government and a stable constitution.[4] The aristocrats, on the other hand, desired the restoration of the monarchy with all its abuses. Their income depended largely on the maintenance of the privileges which the revolution would destroy.

While the court and the moderate parties were scheming together to get the king and the assembly out of the power of the popular party, the patriots were growing more and more uneasy over the situation. Regarding the queen and the court with the most intense hostility, distrusting the ministers and detesting the moderates as traitors to their country, they feared for the success of the revolution. For a month there had been no progress.[5] The 4th of August decrees were the very corner-stone of the free government they hoped to establish. The suppression of feudalism had been unanimously demanded by the *cahiers*. France as a whole favored the revolution.[6]

[1] *Revue historique*, LXVII, 274.
[2] *Ibid.*, LXVII, 276.
[3] Montlosier, *Mémoires*, I, 279; *Revue historique*, LXVII, 276.
[4] De Staël-Holstein, *Correspondance diplomatique*, 130.
[5] *Revue historique*, LXVII, 253.
[6] Young, *Travels in France*, passim.

As has been seen, the thought of bringing the king to Paris for safety had found expression at the time of the August riot. It was understood that the king was well disposed towards the reform movement, but that he was under the influence of those whom he was too weak to resist. Mathiez quotes *Le triomphe de la nation:* "There was but one cry after the 14th of July, to save the king, this good king that loves us all, to take him away from seductions and obsessions, and break his fetters that he may deign to break ours."[1]

On the 26th of August the following conversation occurred between Dussaulx, a royalist, a member of the Academy and of the commune, and Augeard the farmer-general:[2] "This affair will never be well settled so long as the king resides in his château. It was a great mistake on the 16th of July not to have kept him. The dwelling place of a king ought to be in his capital." "You are right," replied Augeard, "but who in his states has the right to force him to take up his residence there?" "When it is for the welfare of all," responded Dussaulx, "he will have to be forced to it, and it will come to that."[3] It had not yet come to that at the time of the August riot, but the thought had been expressed and it spread until it became very general, that the king should be in Paris.

Reports that foreign countries were preparing to take part in the affairs of France increased the purturbation of the patriots. *Les révolutions de Paris* for September 30 contained, under extracts from English papers, the news that "Distinguished foreigners from the court of Spain are in England for the purpose of engaging the English cabinet in a plan to reestablish the monarchical authority in France. There is much talk of a treaty of peace between the emperor and the porte. If the emperor in conjunction with Spain should take measures to reestablish the monarchical dignity in France the national assembly and the spirit of democracy which have lately prevailed in that realm will experience a violent check."[4]

[1] *Revue historique*, LXVII, 252.
[2] *Ibid.*, LXVII, 249.
[3] Augeard, *Mémoires secrets*, 194.
[4] *Révolutions de Paris*, No. XII, 50.

Commenting on this news Camille Desmoulins said: "The emperor has just made peace with the Turks to be in condition to send forces against us; the queen, certainly, would like to go and join him, and the king, who loves his wife, would not wish to be separated from her; if we permit him to leave the realm it would be necessary that we at least take the dauphin as a hostage; but I believe that we should do better not to be in danger of losing this good king, to send a deputation to him, to get him to shut up the queen in Saint-Cyr, and to *bring the king to Paris where we should be surer of his person.*"[1]

This speech is reported by the Venetian ambassador as a "barbarous and sanguinary motion," made on "the pretext that the so-called aristocratic party is seeking to get the power in the assembly,"[2] and such it doubtless appears from an outside point of view. But the matter of power in the assembly getting into the hands of the aristocrats was looked at more seriously by those who hoped for a free government. The following is from the rough draft of a letter written by Barnave on the 4th and 5th of October: "If you could see with your own eyes that the ministers, not excepting Necker, and the majority of our assembly never wished any constitution; that they have never had a moment of superiority without trying with incredibly bad faith to overthrow all that they had appeared to consent to; that their relations in the extent of the realm embrace almost every exercise of authority; that since the decrees of August 4 almost all the governing part of the nation has become our enemy and the enemy of liberty; that to give power to the ancient order in these circumstances would be most certain to reestablish it, to give it the means of annihilating us almost without a struggle since the government and the majority of the assembly would have been for it . . . ready to declare themselves in case the fear or wish of the nation strongly expressed should not restrain them."[3] Enough has been quoted to show that Barnave believed the revolution in very great danger. The suggestion that the "fear or

[1] *Revue historique*, LXVII, 253.
[2] Capello, *Dispacci degli ambasciatori Veniti*, 60.
[3] *Revue historique*, LXVII, 272–73.

wish of the nation strongly expressed" could alone restrain the enemies of the constitution should not be overlooked. A month later he spoke of the October insurrection in these terms: "Paris believed it her duty to save the public liberty a second time,"[1] and this, says Mathiez, was the opinion of all patriots. As Loustalot said a "second access of revolution was necessary."[2]

After the regiment of Flanders had been called to Versailles the popular leaders were all agreed on the necessity of forcing the king to establish himself in Paris.[3] The newspapers were full of demands for energetic measures. The following appeared in the *Révolutions de Paris,* September 20: "We ought not to expect to obtain a constitution for the nation from the ministerial party in the assembly, i. e., from the nobles, clergy, and deputies who have feudal properties, or who aspire to court favors. They would make a constitution for the court. What then shall we do? Give up hope, or go to Versailles and tear from the assembly the traitors to their country?"[4] In the next number occurs the much quoted expression on the necessity for a new "access of revolution."

*La Chronique de Paris* of the 25th of September proposed to "invite the king and queen to come and pass the winter in Paris," and expressed the wish that the "assembly, too, might come to sit in the Louvre."[5] Marat, in *L'ami du Peuple,* demanded more energetic measures: "Convinced that the national assembly can no longer do anything for the welfare of the nation whose decrees have been abandoned in a cowardly manner, and whose rights have been sacrificed (unless by retracing its steps, it reforms its dark decrees), I believe it can not be too soon dissolved."[6]

It was felt that neither the king nor the assembly seriously desired the 4th of August decrees, and that all hopes of the revo-

[1] *Revue historique*, LXVIII, 273.
[2] *Révolutions de Paris*, No. XII, 31.
[3] *Revue historique*, LXVIII, 265, 269.
[4] *Révolutions de Paris*, No. XI, 14.
[5] *Revue historique*, LXVIII, 265.
[6] Marat, *L'ami du peuple*, No. 17, pp. 65, 66.

lution would be lost unless these decrees were carried out. Therefore measures should be taken to "get the king and the assembly away from the pernicious influence of Versailles at any cost.[1]

It was only too evident that the king was disposed to favor the plans of counter-revolution, and very unwilling to accept the proposed reforms and constitution. The queen was winning her cause. The aristocrats were happy in the hope of victory. But the patriots were grimly determined never to yield what they had won for France. They knew that the country was behind them. They needed but the spur of some new aggression on the part of the court to be ready for desperate deeds. This incentive came in the banquet of the body-guards and its attendant circumstances.

## III

### MILITARY COMPLICATIONS

Before studying the immediate causes which precipitated the insurrection, it is necessary to go back and take into account the general situation of military affairs, the position of the French guards and the share they had in bringing about the call of the regiment of Flanders, the attitude of the body-guards of the king toward the revolution, and the fact of secret enrolment of new troops in the royal service.

Before the 14th of July the French guards shared with the body-guard the honor of protecting the king.[2] But when the moment came to choose or sacrifice the patriotic cause, they abandoned their post at Versailles and joined the revolution. Their action afterwards received the approval of the king, who authorized them to remain in Paris and become a part of the citizen militia.[3]

Their share in the triumph of taking the Bastille made them popular heroes. The commune recognized their service to the state by granting to each of them a certificate of acknowledgment

[1] *Revue historique*, LXVIII, 266.
[2] Deux amis de la liberté, *Histoire de la révolution de France*, III, 107.
[3] Lafayette. *Mémoires*, II, 271.

of the city's gratitude.[1] They received other marks of distinction. It was proposed by one of the districts that a gold medal be given to each soldier of the French guards who had helped to bring about the revolution. This proposition was at once seconded by the other districts.[2] The demand seemed to involve unnecessary expense at a time when extravagance was a crime, but the public power in Paris at this time was with the districts,[3] whose open sessions were crowded and very animated. Fortunately the guards themselves requested that the medal be made of a less expensive metal than gold. They wished it to be known that they were disinterested.[4] Their patriotism was further rewarded by public gifts and newspaper fame.[5] Their favor was sought by all parties. Courted by the aristocrats who hoped to detach them from the popular cause, and flattered by the attentions heaped upon them, they soon began to regret their former privilege of guarding the king. Citizen militia seemed ignoble by comparison.

Towards the middle of September they began to talk of going to Versailles to resume their places in the guard of the king.[6] They had heard that a new corps was forming to replace them at court. Rumors were also current that the king was to go to Metz.[7] The French guards were patriots, as we have seen. They therefore strongly objected to letting the counter-revolutionists carry off the king.[8] Lafayette succeeded in dissuading them from carrying out their design to go to Versailles. But he feared the consequences of the alarm at court if the matter should

[1] *Actes de la commune de Paris*, I, 87.

[2] *Ibid.*, I, 100.

[3] Capello, *Dispacci degli ambasciatori Veniti*, 62; *Revue historique*, LXVIII, 269. Mathiez says: "Les districts sont la vraie force publique." In a note he gives the testimony of Fitzgerald, chargé d'affairs from England, as follows: "The sixty districts, which are absolutely so many little sovereignties within the metropolis, exercise the most despotic rule over all."

[4] *Actes de la commune de Paris*, I, 121.

[5] *Revue historique*, LXVIII, 268: "Les estampes reproduisent leurs traits, les brochures d'actualité se placent sous leur patronage, les journaux racontent leurs faits et gestes."

[6] Montlosier, *Mémoires*, I, 271.

[7] *Ibid.*, I, 276.

[8] *Revue historique*, LXVIII, 268.

become known in that city, and he wrote a letter to Saint-Priest informing him of the plan which the French guards had for a moment entertained of going to Versailles, but assuring him that all danger was over, that the idea had been given up.[1]

Doubtless Lafayette sincerely believed there was no longer any real danger; but the public mind was too much on the alert, and circumstances were too suspicious to justify any assurance of peace and quiet. It was known that the body-guard, whose three months of service ended the 1st of October, were retained together with those who entered the service at that time.[2] The number of the guards was in this way doubled. For some reason this body of troops had not yet taken the oath to the nation, nor changed the white cockade of the Bourbons for the tri-color of the revolution.[3]

It was currently reported, moreover, that this guard was about to be reinforced, that a new corps was being recruited to fill the place left vacant by the defection of the French guards,[4] that there was "a list of 30,000 names including old officers, *chevaliers de St. Louis,* and gentlemen who have agreed to join the body-guard," and "that the plan of the aristocratic leaders is to carry off the king to Metz in order to be able to make war in his name upon his people."[5] These rumors were only too well founded. By the confession of the Abbé Douglas before the committee of investigation of the national assembly on the 6th of October, the facts came to light. A regiment of volunteers was to replace the French guards in the service of the king, under the name of guard of the royal household. Fontainebleau was fixed upon as the recruiting place. The officers were to be chosen from the old French guards. Fifteen hundred men were bound by agreement to accompany the king to Metz.[6] Four

[1] Lafayette, *Mémoires*, II, 333.

[2] *Révolutions de Paris*, No. XIII, 4.

[3] Deux amis de la liberté, *Histoire de la révolution de France*, III, 127.

[4] *Ibid.*, III, 121; *Revue historique*, LXVIII, 287.

[5] *Révolutions de Paris*, No. XIII, 6.

[6] *Revue historique*, LXIX, 64. From the "Interrogatoire de l'abbé de Douglas, comité des recherches de l'assemblée nationale."

thousand uniforms had been ordered of a tailor for these new troops.[1]

It had, indeed, been the desire of the aristocrats for a long time to strengthen the position of the king by increasing the number of troops at Versailles. The necessity for this had, as we know, been agreed to by the moderates at the end of August. And two weeks later, when the demands of the assembly for the immediate promulgation of the decrees of August 4 became so imperative as to alarm the king, the regiment of Flanders was sent for.[2] According to Mathiez this regiment had been on its way two days on the 18th of September when Louis XVI. sent to the assembly his long *mémoire* explaining the necessity for delaying the promulgation of these decrees.[3]

It was on this same day that Lafayette's letter, concerning the proposed movement of the French guards, was used by Saint-Priest for a purpose never intended by its author.[4] The regiment of Flanders was already on its way to Versailles before the fear arose that the unexpected arrival of troops might rouse that most dreaded of all instruments of revolution, the Paris mob. Lafayette's letter served as a much desired pretext for shouldering the responsibility of the decision upon the staff and the municipality of Versailles. The letter was not made public,[5] but its message was so used as to create alarm and bring about a formal requisition on the king to send for more troops.[6] The thing was so skilfully managed that many good patriots were deceived.[7] But that the threatened invasion of the guards was not a reason for sending for the regiment of Flanders is shown by an examination of dates. It was on the 16th of September that this regiment left Douai for Versailles.[8] The summons could not have been sent from the latter city later than the 14th.

[1] *Revue historique*, LXVIII, 287.
[2] *Ibid.*, LXVII, 280; Weber, *Mémoires*, I, 421.
[3] *Ibid.*, LXVII, 281.
[4] *Ibid.*, LXVIII, 264, 285; Lafayette, *Mémoires*, IV, 149.
[5] *Révolutions de Paris*, XIII, 4.
[6] *Revue historique*, LXVII, 281, and LXVIII, 284.
[7] Bailly, *Mémoires*, II, 381; Duquesnoy, *Journal*, I, 362.
[8] *Actes de la commune de Paris*, II, 48, 49.

Lafayette's letter was written on the 17th,[1] and presented to the staff on the 18th. It is therefore manifestly impossible that it could have been the cause of sending for this body of troops. Is it not probable that the reason for this step lay deeper? At the end of August, Versailles had been threatened by a mob from the Palais Royal, incensed by the action of the moderate deputies on the veto and alarmed for the safety of the decrees of August 4. If we remember that the king was obstinately opposed to these decrees, that the ministers believed that their promulgation would bring anarchy; and if we recall that the moderates were so strong in the assembly as to be believed in the majority, and that the plan to transfer both the king and the assembly to the provinces had not yet been given up, and if we reflect that the aristocrats had never ceased to work and plot for the complete restoration of the ancient régime, we shall, I think, accept Mathiez's interpretation of the calling of the regiment of Flanders, that it was "the first step of the king and his ministers in the way of open resistance."[2]

Not without lively opposition was the deed accomplished. The municipality of Versailles had ratified the demand for reinforcements,[3] but the staff was by no means unanimous. On the 21st of September, Mirabeau rose in the assembly to contest the right of the municipality of Versailles to call troops without the consent of the national assembly.[4] Before the arrival of the troops, members of the Breton club, Lafayette, and the commune of Paris had united in the demand that the regiment of Flanders be sent away again.[5] The reply which they received from Saint-Priest destroyed their last hope of success by legal means.[6]

[1] Bailly, *Mémoires*, II, 380; *Revue historique*, LXIX, 61.

[2] *Revue historique*, LXIX, 63.

[3] *Pièces justificatives du rapport de la procédure du châtelet*, 35.

[4] *Procès-verbal de l'assemblée nationale*, No. LXXX, 4; *Courrier de Provence*, No. XXV.

[5] *Revue historique*, LXVIII, 269.

[6] Campan, *Mémoires*, II, 294. The reply which Saint-Priest sent to this demand is mentioned in the "Abregé des circonstances du depart de Louis XVI, pour Paris le 6 octobre, 1789," written by Saint-Priest and contained in Mme. Campan's *Mémoires*. "Je lui répondis, le plus modérément que je pus, que cette demande d'un régiment de ligne était une suite naturelle de

The regiment arrived on the 23d of September.[1] On the same day, the king asked for a list of the officers of the national guard who had gone to meet it. And the next day he sent an autograph letter expressing in flattering terms his gratification that they had been so prompt to receive the new troops, and promising not to forget the attachment and confidence thus shown to him.[2] An attempt was also made by the queen to conciliate the national guards. On the 29th of September she sent for the lieutenant-colonels to announce to them that she was having flags made to present to each of their companies.[3]

Meanwhile Paris was in the greatest state of fermentation. The districts met and sent deputations to the commune to express their uneasiness over the movement of troops about Paris, and to ask if the national assembly was cognizant of these things. The commune asked Bailly to write and demand information from the ministers concerning the "regiment of Flanders and all other troops that may have been called." The reply not being satisfactory, the demand was repeated the following day.[4]

The most intense alarm was felt by the patriots who looked upon the arrival of the regiment as a defiance and a menace.[5] "It was reported that already formidable armies were marching on Paris and Versailles, that a cordon of troops was formed around the two cities, and the nation was in danger."[6] "It was not doubted that the regiment of Flanders was but the advance guard of the enemy, that the body-guard, doubled and increasing every day . . . was but the nucleus of the army which was silently preparing to fall upon the patriots."[7]

The people of Paris, distracted by famine, suspicious of conspiracies, and seeing the ranks of their enemy increase day by

l'avis donné par une lettre de M. de La Fayette. J'ajoutai que je lui repondais ainsi de moi-même le roi ne m'ayant pas autorisé à répondre à une question que Sa Majesté n'avait pu imaginer qu'on osât faire à son ministre."

[1] *Revue historique*, LXVIII, 286.

[2] *Pièces justificatives du rapport de la procédure du châtelet*, 36.

[3] *Revue historique*, LXVIII, 286.

[4] *Actes de la commune de Paris*, II, 37–39, 51–56.

[5] *Révolutions de Paris*, No. XII, 31.

[6] Deux amis de la liberté, *Histoire de la révolution de France*, III, 115.

[7] *Ibid.*, III, 144.

day, were in that extremely sensitive state where any indiscretion on the part of the court would precipitate an outbreak. The banquet given by the body-guard to the officers of the regiment of Flanders furnished the provocation, and the insurrection followed.

There had not been at all times the best of feeling between the body-guard and the court. The occasion of the banquet given to the regiment of Flanders was seized by the court to conciliate the guard and restore their loyalty to the king. The feast was made an affair of unusual magnificence. The theater of the château, heretofore reserved for court festivities, was granted them for their repast.[1]

The list of invited guests included not only the officers of the regiment of Flanders, but also those of all the other troops at Versailles.[2] They drank the health of the king, the queen, the dauphin and the royal family; but no toast was drunk to the nation. Whether purposely omitted or expressly rejected it is impossible to know because of conflicting testimony.[3]

In the midst of the festivities, the queen appeared, and made the round of the tables, leading the dauphin,[4] eliciting the enthusiastic applause of the delighted soldiers. The king also graced the banquet by his presence, the orchestra played the famous air, "O Richard, O my king! the world abandons thee," and loyalty expressed itself in enthusiastic cheers and applause.[5]

[1] Deux amis de la liberté, *Histoire de la révolution de France*, III, 129.

[2] *Révolutions de Paris*, No. XIII, 5; *Courrier de Provence*, No. XXXI; Weber, I, 422; Duquesnoy, I, 397; Campan, II, 295.

[3] Deux amis de la liberté, *Histoire de la révolution de France*, III, 129; De Staël-Holstein, *Correspondance diplomatique*, 129.

[4] There are several versions of this. I have followed Weber (I, 423) who says: "Marie-Antoinette, par un movement irresistible imitant son auguste mère, prit M. le dauphin par la main et le promena autour des tables." This is the version followed by the *Révolutions de Paris* (No. XIII, 5). According to Ferrières (I, 281), the queen "prend le dauphin dans ses bras, et fait le tour de la table au milieu des acclamations les plus bruyantes." This seems highly improbable and is doubtless a reminiscence of the famous act of Maria Theresa. Morris states (I, 168) that "Her Majesty descended from her box, and with her son and husband, graceful and tall, with a truly queenly dignity, walked through the ranks of the soldiers." De Staël-Holstein gives (p. 129) yet another version. See also *Courrier de Provence*, No. XXXI.

[5] Campan, *Mémoires*, II, 71.

The guests, with drawn sword in hand, drank to the health of their royal visitors, who accepted this homage and withdrew.[1] "From this time the feast degenerated into an orgy." Intoxication took the place of enthusiasm, and amidst the wild and foolish excesses that followed, the tri-colored cockade of the nation was insulted,[2] and the nation itself made the object of most frightful imprecations.[3]

The most alarming feature of this whole matter was that the banquet of the body-guard was no mere accident, no unforeseen outburst of loyalty. There is evidence to show that it had all been planned beforehand for dramatic effect, to dazzle and win the allegiance of the troops to the court party. D'Estaing's letter to the queen speaks specifically of a premeditated purpose not to drink the health of the nation.[4]

The effect of the demonstration on the court party was to remove all restraint. They seem to have thought the cause already won, and that there was no longer necessity for concealment. After the banquet, ladies of the court exerted themselves openly to win proselytes in the château. National guards wearing the tri-colored cockade were accosted and asked to change it for the white, emblem of the ancient régime, or the black, the color of the queen.[5] Several officers of the national guard appeared with white cockades;[6] men presented themselves at the review wearing this badge;[7] and a gentleman wearing the national uniform was refused admittance to the château and informed that the insult was due to his dress.[8] As if to cap the defiance to the friends of the revolution, Marie Antoinette, on

[1] Campan, *Mémoires*, II, 296; Deux amis de la liberté, *Histoire de la révolution de France*, III, 131.

[2] De Staël-Holstein, *Correspondance diplomatique*, 130; *Courrier de Provence*, No. XXXI; Duquesnoy, I, 397.

[3] *Révolutions de Paris*, No. XIII, 5; Duquesnoy, *Journal*, I, 397.

[4] *Revue historique*, LXVIII, 289.

[5] *Révolutions de Paris*, XIII, 5; Weber, I, 426; *Courrier de Provence*, No. XXXI; *Pièces justificatives du rapport de la procédure du châtelet*, No. IX.

[6] *Ibid.*

[7] *Révolutions de Paris*, No. XIII, 6.

[8] Deux amis de la liberté, *Histoire de la révolution de France*, III, 136.

the 2d of October, received a deputation from the national guard, come to thank her for her gift of flags. She said to them, "I am very glad to have given flags to the national guard of Versailles. The nation and the army should be attached to the king as we are ourselves to them. I was enchanted with Thursday,"—the day of the banquet.[1]

The news of the banquet reached Paris on the following day, and the alarm spread rapidly. There was no longer any doubt of the reality of the plots which, for some time, the pamphlets and journals had been attributing to the court, the ministers, and the majority of the assembly. *La Chronique de Paris* denounced the plot of the aristocrats on the 4th. Marat condemned "the orgy of Versailles in burning terms, and closed by a veritable call to arms."[2] The agitation increased in all quarters of the city. Wherever a man appeared wearing a white or black cockade he was attacked and his emblem torn from him, and he himself arrested or threatened.[3] The districts assembled and sent deputations to the commune to demand that it take necessary measures. The city officers were alarmed "at the outrage against the nation and the commune, committed by persons who have allowed themselves to abjure and discard a cockade which has been adopted as a symbol of union and of liberty." The commanders of the battalions were ordered to remain under arms, and a decree was passed forbidding individuals to wear any other than red, blue, and white, the national colors.[4]

At the Cordeliers, Danton secured a decree to send a deputation to the commune to urge that the "commanding general go to Versailles the next day to ask, in the name of all the citizens of Paris, that the troops be sent away immediately," etc., etc.[5]

[1] Deux amis de la liberté, *Histoire de la révolution de France*, III, 136.

[2] *Revue historique*, LXVIII, 291. Mathiez quotes "selon le mot de Desmoulins;" "Tous les bons citoyens doivent s'assembler en armes, envoyer un nombreux détachement pour enlever toutes les poudres d'Essonne; chaque district doit retirer ses canons de l'hôtel de ville."

[3] Deux amis de la liberté, *Histoire de la révolution de France*, III, 149, 150.

[4] Deux amis de la liberté, *Histoire de la révolution de France*, III, 150.

[5] *Revue historique*, LXVIII, 292. Mathiez quotes from the *Courrier de Versailles*.

The Palais Royal, that rallying place of thousands of homeless dwellers of Paris, the lawless, the idle, the discontented, was in permanent session, and more than ever a hot-bed of insurrection and rebellion.[1] On Sunday, the 4th, the place was crowded with women who cried out that "to-morrow things would go better, that they would put themselves at the head of affairs." One "whose appearance indicated a woman above the middle class" said that Paris lacked bread and they must go to-morrow and demand it of the king and royal family.[2]

The French guards, patriots at heart and jealous of those who had usurped their places at court, were in sympathy with the people. They heard and applauded the popular orators. The national guards dispersed the crowds so gently that evidence was afterwards given that "no precautions were taken against the agitators."[3]

The discontent of the French guards at seeing their places at court filled by strangers, the alarm caused by the increased number of troops about Versailles, the doubling of the body-guard, the enlistment of a new corps, and the calling of the regiment of Flanders,—all these military complications helped to make the position utterly intolerable to the friends of the revolution. And finally the banquet of the body-guard, with its open insults to the popular cause, was like a spark to a powder magazine,—the explosion was inevitable.

## IV

### PERSONAL AND OTHER INFLUENCES

To determine with any exactness the rôles played by individuals in the October insurrection is an impossible task. I shall therefore confine myself to a discussion of some statements that have been made, some opinions that have been held, and to a suggestion of probabilities.

[1] Bailly, *Mémoires*, II, 232, 233.
[2] *Revue historique* LXVIII, 293.
[3] *Ibid.*, LXVIII, 293. Mathiez quotes from the *Procédure du châtelet.*

Accusations against the Duke of Orleans began to be heard in the latter part of August. Among his accusers was Jefferson. A letter written to John Jay on the 27th of August contains the assertion that the faction of Orleans "wish to dethrone the reigning branch and transfer the crown to the Duke of Orleans."[1] Two days later De Staël-Holstein, the Swedish ambassador, wrote in his home despatch: "It is believed that the Duke of Orleans is at the head of a formidable party."[2] And on the 17th of September he expressed himself more positively: "The party of the Duke of Orleans takes the lead in extravagant and violent opinions. I believe it is certain that this prince has high pretensions."[3] A few days later Bailly mentions the "fearful faction at the Palais Royal working under the name of *Égalité*."[4] Lafayette believed there was "no doubt that the party of the Duke of Orleans wished to place him on the throne."[5] As for this Orleans party he goes so far as to name the principal members of it.[6] Lafayette even claims that the duke tried to win his adherence to the proposed measures, that he came to see him several times on the subject.[7]

The Duke of Orleans was also accused of using his money freely to feed the flame of revolution.[8] Young states in his journal for June 25: "It is asserted expressly that the mobs have been excited and instigated by the leaders of the commons, and some of them paid by the Duke of Orleans."[9] And two days later, speaking of the brilliant displays of fireworks at the Palais Royal, and the question as to who paid for them he says: "There is no doubt of its being the Duke of Orleans' money."[10] Mathiez refers to the *Procédure du châtelet* for evidence of the fact that

[1] Jefferson, *Memoir, Correspondence and Miscellanies*, III, 20.
[2] De Staël-Holstein, *Correspondance diplomatique*, 112.
[3] *Ibid.*, 126.
[4] Bailly, *Mémoires*, II, 396.
[5] Lafayette, *Mémoires*, II, 335.
[6] *Ibid.*, IV, 138.
[7] Lafayette, *Mémoires*, II, 355–57.
[8] Capello, *Dispacci degli ambasciatori Veniti*, 77.
[9] Young, *Travels in France*, 122.
[10] *Ibid.*, 125.

much money was distributed before the October outbreak, not only among the troops but also among the people.[1]

There was strong suspicion that the troubles in France were fomented by English subsidies. The Swedish ambassador found in the suspicion "much probability." He also believed it "quite probable that the Duke of Orleans has come to an understanding with this power."[2] "The sums of money scattered among the people," he says, "are not to be explained by the fortune of the Duke of Orleans."[3] According to the French *chargé d'affaires* at London, England was disposed to take advantage of the situation in France to force unpleasant sacrifices.[4]

However this may have been, it is certain that after the October insurrection charges against the Duke of Orleans multiplied. On the 19th of October, Capello wrote that a "conspiracy had been discovered," from which it appeared that this prince had been the "defender of the popular cause to further his own ends." "Being aware," says Capello, "of the project for the king to abandon Versailles to go to Metz, a project said to have been formed by the queen, this first prince of the blood planned everything to bring about the destruction of the king and the royal family on the way; then, favored by the insurrection, to have himself named lieutenant general of the realm," etc., etc. Capello does not vouch for the truth of this report, but reserves his judgment until he has further information. At the same time he asserts that the accusations are based on the "depositions of many people."[5]

The Swedish ambassador asserts that the party of Orleans wished to get the king away from Versailles "in the hope that he would be dethroned, if once he went away."[6]

[1] *Revue historique*, LXVII, 261, and LXVIII, 274.

[2] De Staël-Holstein, 112, 126.

[3] *Ibid.*, 142.

[4] Sorel, *L'Europe et la révolution française*, II, 30. See also correspondence between Dorset and Montmorin in *Archives parlementaires*, VIII, 287, 342.

[5] Capello, *Dispacci degli ambasciatori Veniti*, 76.

[6] De Staël-Holstein, *Correspondance diplomatique*, 134. See also Duquesnoy, *Journal*, I, 444, 449, 462.

From so much concurrent testimony of reputable witnesses we may be sure of two facts:—that there was an Orleans party, and that this party was intriguing for power. But to know just how much truth there is in the charge that the insurrection was brought about by this faction, or just how far the duke was himself responsible for the acts of his party, are very difficult questions to answer. A study of the character of the witnesses, their opportunities for gaining information, and also a knowledge of the character of the duke himself may help somewhat.

The foreign ambassadors in Paris at this time were men of character and ability, and presumably free from party prejudice, but they seldom give the source of their information. The depositions mentioned in Capello's despatch last cited are not to be accepted as conclusive evidence. Indeed they sometimes contradict each other.[1] Lafayette was persuaded that the Duke of Orleans played an important part in the October insurrection. But was not Lafayette a prejudiced witness? A man of high ideals, of private virtue and public honor, he could not but despise a man so notorious for his vices as was Philippe of Orleans.[2] The most suspicious circumstance in connection with the charges against the duke is his going to England immediately after the outbreak, in obedience to Lafayette's most urgent and threatening insistence[3] on a mission that was merely a pretext and which deceived nobody as to the true character of his banishment.[4] The acceptance of such a mission under such circumstances is in itself a confession of guilt. The efforts made by the friends of the duke to keep him from going seem to show that they understood this. Lafayette gives the following account of the matter: "On the 7th of October Lafayette demanded an interview. After a conversation which Mirabeau called 'very imperious on one side and very resigned on the other' it was resolved that the Duke of

[1] *Revue historique*, LXVIII, 276.

[2] *Ibid.*, LXVII, 259. Jefferson, *Memoir, Correspondence and Miscellanies*, III, 20. "The duke . . . sunk in debaucheries of the lowest kind, and incapable of quitting them for business; not a fool, yet not head enough to conduct anything," etc., etc.

[3] Montlosier, *Mémoires*, I, 315; Lafayette, *Mémoires*, II, 357, 358.

[4] De Staël-Holstein, *Correspondance diplomatique*, 136.

Orleans should go to England with a kind of mission to justify his departure; but he changed his mind the same evening on the advice of his friends. He informed Lafayette of it; Lafayette gave him a second rendezvous and made him promise to leave within twenty-four hours. . . In the night Orleans changed his mind again, and Mirabeau having taken it upon him to denounce in the assembly Lafayette's conduct in giving orders to a representative of the people, he, Orleans, wrote at daybreak that he would not go. A third rendezvous was immediately set by Lafayette . . .; the result of the conversation was that Orleans went."[1]

If such was the character of the Duke of Orleans, so weak, so cowardly, so irresolute, can we believe that he was the leading spirit in a conspiracy to overthrow the government? Is it not much more probable that he was the willing instrument of bolder men? De Staël-Holstein affirms that the Duke of Orleans, "instead of leading his party, allows himself rather to be drawn on by it; and when the instant to act arrives courage fails him."[2]

From the beginning of the revolution the Duke of Orleans had been very popular with the common people. On the 12th of July they had carried his bust with Necker's in procession through the streets of Paris.[3] He made every effort to gain the good graces of the patriots, even to the extent sometimes of discourtesy to the court. Capello speaks thus of his conduct at Versailles on the day of Saint-Louis, the *fête* day of the king: "For a climax of humiliation, the Duke of Orleans, with an insolence truly disgusting in a Bourbon and a first prince of the blood, alone, among those who accompanied his majesty, wore the cockade of the third estate."[4] A royal prince who was hated

[1] Lafayette, *Mémoires*, II, 357, 358; Morris, *Diary and Letters*, I, 202, 222, 223. Morris reports that Lafayette had said of the Duke of Orleans: "Ses lettres de créance sont des lettres de grâce," but afterwards denied that he had used such an expression, "puisqu'il n'y a aucun indice contre le duc d'Orleans." Morris thought the friends of the duke were likely to convict him by their zeal in circulating absurd stories, such as that "England gives two millions sterling to make mischief in this country." In November the Duke of Orleans was offering 20 per cent for a loan of 500,000 francs.

[2] De Staël-Holstein, *Correspondance diplomatique*, 142.

[3] Flammermont, *La journée du 14 Juillet, 1789*, CLXXVII.

[4] Capello, *Dispacci degli ambasciatori Veniti*, 58.

by the court and who espoused the popular cause was looked upon as a natural leader. Whether it be true, as Barras asserts, that the Duke of Orleans would "naturally have been placed on the throne at this time if he had shown the slightest ambition,"[1] it appears evident that by reason of his lack of character he was more led than leader in the movement. And although his friends made use of him as far as possible to further their own interests, and although he doubtless hoped to profit by their intrigues, we have seen that the insurrection of October had other and more potent causes. Malouet's judgment in the matter appears most worthy of acceptation: "Even if the Duke of Orleans had never existed we should probably have seen the same scenes . . . the course of events would not have been changed."[2]

The Count of Mirabeau was suspected and accused of complicity in the conspiracy attributed to the Duke of Orleans.[3] Lafayette believed that at the time of the October troubles "Mirabeau was closely allied with the Orleans party which directed the movement."[4] Dumont, in his *Recollections of Mirabeau,* says, "I remember hearing him speak somewhat favorably of this prince" (the Duke of Orleans), and after some discussion concludes: "It is impossible not to think there was some connection between them."[5] The attitude of Mirabeau towards the pretended mission to England is taken by Mathiez as evidence that his own interests were bound up with those of the Duke of Orleans. When the note containing the duke's final decision to leave the country was received by Mirabeau, he read it and then held it out to his friends exclaiming "Read! They pretend that I am of his party. I would not have him for my valet!"[6] The speech prepared to denounce Lafayette in the assembly is also

[1] Barras, *Mémoires*, I, 65.

[2] Malouet, *Mémoires*, I, 331; *Revue historique*, LXVII, 276.

[3] Duquesnoy, *Journal*, I, 412, 462; Dumont, *Recollections of Mirabeau*, 13; Capello, *Dispacci degli ambasciatori Veniti*, 77.

[4] Lafayette, *Mémoires*, IV, 45.

[5] Dumont, *Recollections of Mirabeau*, 141.

[6] Loménie, *Les Mirabeau*, IV, 513; *Correspondance de Mirabeau et de La Marck*, I, 128.

taken as evidence against Mirabeau, on the ground that he "confounds the cause of the Duke of Orleans with his own."[1]

The testimony of La Marck, that Mirabeau objected to the exile of the Duke of Orleans because he feared Lafayette's domination and the triumph of republican ideas,[2] is called into question by Mathiez, who claims that La Marck was not a disinterested witness, but a "confidant and in some sort an accomplice," and "in defending his old friend he was merely defending himself."[3]

"Mirabeau's conduct during the days of the 5th and 6th of October," says Loménie, "was of an equivocal character, at least, and afforded matter for suspicion."[4] Yet "even his enemies confess that he was too indiscreet to conceal his plans,"[5] he was "as prompt to write as to speak, and all his negotiations, all his secret plots found expression in continued correspondence that has been gradually coming to light for a hundred years." "Would it not be astonishing," asks Loménie, "if his intrigue with the Duke of Orleans should be the only one that left no written trace?"[6]

It is true that Mirabeau wanted to get into the ministry at this time, and that Lafayette was his confidant in the matter.[7] He was ambitious and needed the income that the ministry alone could pay.[8] He was also capable and could see what he might do for France. It is also true that he was engaged, not long after, in an "intrigue to displace Necker for Tallyrand."[9] Doubtless a man of his ability chafed under Necker's incompetence.

I can do no better than reproduce Loménie's conclusion of the matter: "Mirabeau, like many others, had the thought of plac-

[1] *Revue historique*, LXVIII, 280.
[2] *Correspondance de Mirabeau et de La Marck*, I, 127.
[3] *Revue historique*, LXVIII, 281, 282.
[4] Loménie, *Les Mirabeau*, IV, 483.
[5] *Ibid.*, 503; *Correspondance de Mirabeau et de La Marck*, I, 112, 113.
[6] Loménie, *Les Mirabeau*, IV, 506.
[7] Morris, *Diary and Letters*, I, 193; De Staël-Holstein, *Correspondance diplomatique*, 42, Duquesnoy, *Journal*, 462, 463.
[8] *Correspondance de Mirabeau et de La Marck*, I, 129.
[9] Duquesnoy, *Journal*, I, 370, 335, 355.

ing at the head of the government, in case Louis XVI. should not be able to maintain himself, a prince naturally fitted for the position by the political opinions which he held and by his place in public esteem; but this thought, conceived about the time of the July insurrection, far from taking root in his mind, disappeared as the character of the prince became better known; allied to the friends of the Duke of Orleans, he must also have had a passing intercourse with the Duke of Orleans himself, and have knocked at this door, if we may so express it, as he had knocked successively at all the doors that might open a career for his impatient ambition; but he has never been either the recipient of the real secrets of the prince and his associates, or engaged to them by a formal compact."[1]

What was the part of Lafayette in the October insurrection? Was it, as Stephens says, to "pose as the savior of the monarchy?" Did he bring the king to Paris "merely to increase his own honor and glory?" As a patriot Lafayette had the success of the revolution at heart. Great danger threatened the cause of liberty. Lafayette shared the general alarm over the arrival of the regiment of Flanders and the boldness of the aristocratic reaction shown in the banquet of the body-guard. He was, moreover, irritated at the "mysterious and irregular use" made of his letter to Saint-Priest.[2] He had refused Montmorin's offer of conciliation with the reply:[3] "If the king fears a riot let him come to Paris. He will be safe there in the midst of the national guard."[4] Lafayette was not without ambition. It is true, perhaps, that he desired "a direct and habitual influence over the decisions of the king."[5] Nor was he invulnerable to "the delicious sensation of the smile of multitudes."[6]

But I have found no evidence that Lafayette was in any way responsible for the movement of the national guard on the 5th

[1] Loménie, *Les Mirabeau*, IV, 507, 508.
[2] *Revue historique*, LXVIII, 264.
[3] *Ibid.*, LXVIII, 287.
[4] Lafayette, *Mémoires*, II, 298.
[5] *Revue historique* LXIX, 49, quotation from Necker.
[6] Loménie, *Les Mirabeau*, V, 28.

of October. There is, on the contrary, a convincing amount of testimony that, instead of provoking the movement, Lafayette did all in his power to restrain it, and consented to go to Versailles at last only under practical compulsion.[1] "The guard wished to go to Versailles," says the Swedish ambassador, "to avenge the insult to the national cockade on the day of the banquet of the body-guard. . . The Marquis of Lafayette did all in his power to stop them. He was forced to yield to the multitude."[2] According to Montlosier, a deputation from the grenadiers brought the message to Lafayette that the "people are in misery; the source of the evil is at Versailles: we must go to seek the king and bring him to Paris; we must exterminate the regiment of Flanders and the body-guard who have dared to trample the national cockade under foot." And when Lafayette tried to harangue the crowd "his voice was lost in cries of 'To Versailles! To Versailles!'"[3] Capello says that Lafayette, "unable to resist, tried to gain time, but was threatened with hanging and obliged to give way to circumstances."[4] The same story is told by Morris: "Lafayette has marched by compulsion, guarded by his own troops who suspect and threaten him. Dreadful situation! Obliged to do what he abhors or suffer an ignominious death with the certainty that the sacrifice of his life will not prevent the mischief."[5] Lafayette's own testimony confirms that already given.[6]

If we consider that these troops were scarcely organized and so undisciplined that they refused to mount guard in the rain,[7] and if we remember that it was Lafayette's duty as a man of honor to protect the king and the national assembly, we shall see little reason to doubt his hesitation to take the responsibility of leading this movement.

[1] *Révolutions de Paris*, No. XIII, 13; Deux amis de la liberté, *Histoire de la révolution de France*, III, 163–64.

[2] De Staël-Holstein, *Correspondance diplomatique*, 130.

[3] Montlosier, *Mémoires*, I, 288.

[4] Capello, *Dispacci degli ambasciatori Veniti*, 74.

[5] Morris, *Diary and Letters*, I, 173.

[6] Lafayette, *Mémoires*, II, 336, also III, 219.

[7] Morris, *Diary and Letters*, I, 156.

Lafayette's part in the insurrection, then, was not one of self-glorification, although his power was unquestionably increased by the results of it.[1] But by placing himself in command he gave dignity and a certain character of legality to the movement which made it formidable to possible resistance on the part of the court.[2]

The influence of persons, therefore, appears not so much a cause of this insurrection as an attempt to reap some benefit from a revolution which was inevitable.

More influential than the intrigues of persons or of parties in precipitating the outbreak was the public press. After the arrival of the regiment of Flanders, the patriotic journals united in proclaiming the necessity for forcing the king to establish himself in Paris.[3] A campaign was commenced against all "enemies of the revolution." I have already quoted enough from the leading newspapers to show the spirit of the press. The commune of Paris was accused of "favoring a new system of aristocracy," Lafayette and Bailly of "allowing the people to starve." Leading members of the assembly were denounced as "traitors to the revolution." The aristocrats were accused of "secret plots and dangerous conspiracies," and the attacks on the queen grew more numerous and more virulent.[4] Pamphlets were circulated that were even more violent than the newspapers. An example was given in the one entitled *When shall we have bread?* The effect of these publications, appearing day by day, can hardly be imagined. At the Palais Royal, the ideas they expressed were constantly discussed by the popular orators, with the result that "the people became strongly impressed with the thought that it was necessary for the success of the revolution to establish the seat of public power at Paris."[5] "It was the press that not only prepared the insurrection and rendered it possible, but which gave it its peculiar purpose and character. All the hatred, all the passions with which the revolted people were animated, all the

[1] *Revue historique*, LXVIII, 264.
[2] *Ibid.*, LXIX, 49.
[3] *Ibid.*, LXVIII, 265.
[4] *Ibid.*, LXVIII, 266.
[5] *Ibid.*, LXIX, 46.

accusations they uttered, all the demands they made had first found expression in the press."[1]

This insurrection, then, was not an unpremeditated outburst of lawlessness, "entirely unforeseen and spontaneous." It was rather foretold and prearranged and carried out with the fixed and conscious purpose of bringing the king to Paris. This was what the papers had been preaching as necessary to the success of the revolution. This was the required remedy for all distress of body or mind. If bread was lacking, the king's presence would bring plenty. If the aristocrats were plotting against the public welfare, their plots would fall harmless if once the king were removed from their influence. From the beginning of the agitation, the chief thought of the insurgents was that they must bring the king to Paris at any cost. We have seen how the women at the Palais Royal announced on the 4th of October their plan of going to Versailles the next day "to seek the king and to bring him to the Louvre." The women who went to the Hôtel de Ville to demand bread, as well as the men who followed them, were all determined to march to Versailles and bring back the king.[2]

One of the demands of the commune, sent by the delegation which accompanied Lafayette, was to this same effect. "The king would give a great proof of his love for the French nation if he would dwell in the finest palace in Europe, in the greatest city of his realm, and among the most numerous part of his subjects." The French guards were represented in another demand of the commune: that "His Majesty would confide the guard of his sacred person only to the national guards of Paris and of Versailles." According to Mathiez, who refers to the *Prócedure du châtelêt* for evidence, the French guards had won over the regiment of Flanders to the popular cause, and had received the assurance from this regiment that it would take no part against the nation in the proposed movement.[3]

[1] *Revue historique*, LXIX, 41, 42.

[2] *Ibid.*, 44; Deux amis de la liberté, *Histoire de la révolution de France*, III, 175.

[3] *Revue historique*, LXVIII, 294.

On the morning of the 5th, the alarm bell was sounded according to a plan announced the day before, to call the people together to go to Versailles after the king. The uprising was general. Beginning at six in the morning, the bells were rung for several hours and the "whole city was put in motion."[1]

To sum up: The causes of the October insurrection were many and complicated. First, the economic conditions, brought about by corrupt administration and stupid legislation, caused untold suffering and prepared the way for revolt. Second, the political situation, the reaction against the revolution, the king helpless, the queen intriguing against the nation, the ministers inefficient, the aristocrats ready to plunge the country into civil war to bring back the ancient régime, the moderates suspected of treason against the popular cause, and the patriots determined to maintain advantages already won,—all these warring elements made an explosion inevitable. Third, the military complications, the jealousy and discontent of the French guards, the alarm caused by the arrival of the regiment of Flanders, and rumors of other forces gathering about Versailles, culminating in furious indignation over the orgy of the body-guard, precipitated the revolt, which, last of all, was helped along by the schemes of ambitious men and the influence of a virulent press. All these things contributed in a greater or less degree to produce the insurrection. "The night of the 4th of August had been the logical result of the revolution of July; the 5th and 6th days of October were the inevitable consequence of the night of the 4th of August."[2]

[1] Deux amis de la liberté, *Histoire de la révolution de France*, III, 159.
[2] *Revue historique*, LXIX, 58.

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## II.—*Formation and Succession Herbaria*

BY FREDERIC E. CLEMENTS

**Drude** (**1896**) was the first to suggest that ecologists should collect and arrange herbaria with reference to plant formations. His suggestion embraced the following details: "Für grössere Museen, in denen der Flora des engeren Heimatgebietes ein besonderes, die zahlreichen Einzelstandorte aufweisendes Herbarium gewidmet ist, lässt sich empfehlen, zur Ergänzung des systematisch angeordneten Hauptherbariums noch ein Formationsherbarium anzulegen, welches etwa den Gang der im Abschnitt IV aneinandergereiheten Hauptformationen einschlägt. In diesem müssen die geselligen Hauptarten der Bestände in den Vordergrund kommen, und die Nebenarten (oder in den offenen Formationen alle Arten) sind dann zweckmässiger nach biologischen Rücksichten (besonders Wachstumsform, Unterscheidung der Ausdauer etc.) anzuordnen als nach dem System, welches nur die Rangfolge in derselben Kategorie zu bestimmen hat. Der Vorteil eines solchen Herbars liegt auf der Hand: wie lehrreich ist es, sämtliche Wasserpflanzen, die Felsbestände, die Wiesen etc. sogleich übersichtlich beisammen zu haben und nunmehr auf den Etiketten die Angaben über Häufigkeit, Standorts-Erfordernis etc. sogleich auf die Formation beziehen zu können!" The first formation herbaria were collected by **Clements** in the Rocky mountains of Colorado during 1900 and 1901, and were distributed in 1902. These were based upon formational structure, and arranged to show vegetation zones, as well as the time, position, and numerical importance of the species. **Engler** (**1901**) made a logical extension of the idea underlying formation herbaria in the formation anlage of the Berlin botanical garden. While formation gardens are intrinsically superior to formation herbaria, the impossibility of reproducing each for-

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mation in detail and with accuracy makes them of much less practical value.

Formation herbaria are not only invaluable records of vegetation, on account of their lists, quadrat charts, and photographs, but they are also as indispensable to the worker in comparative phytogeography as they are useful in class instruction. When collected with reference to the developmental series and arranged in what may be termed *succession herbaria,* they will mark a new period in the study of the development of vegetation. For a phytogeographer concerned with the critical comparison of the vegetation of distant countries, such herbaria will put into his hands, at a great saving of time and expense, a much better and more detailed summary of a distant region than he could possibly obtain without actual residence for several years. It is hardly too sweeping to assert that accurate work in the new field of comparative phytogeography can only be done with such means. The value of formation herbaria in class work is evident. On account of the limitations of time and distance, classes can touch but few formations, and these at every other time than at the growing period. For these reasons, an accurate and complete formational record that can be consulted or studied at any time is all but absolutely necessary for class study in the development and structure of formations.

Formational collections, unlike the ordinary sets of exsiccati, can not be made upon the first visit to a region, or by a single journey through it. The determination of formation limits, of aspects, layers, abundance, etc., must necessarily precede,—a work which alone takes several years. Moreover, collecting itself requires more than one year in a region containing numerous formations. The *Herbaria Formationum Coloradensium* affords an excellent illustration of this. The preliminary study was made from 1896 to 1899; the major part of the collecting was done in 1900 and 1901, while additional numbers were added in 1902–3. Specimens must be taken in both flower and fruit, with the underground parts as complete as possible. Opened corollas are valuable for flower biology, and seeds are highly desirable. In press-

ing, one or two leaves should be arranged with the lower side uppermost to admit of the ready comparison of both surfaces. Seedlings and rosettes should be included whenever present. The number of photographs taken to illustrate each formation should be limited only by considerations of time and expense. The ideal series consists of a general view of each formation, showing its physiographic setting, nearer views of each of its aspects, detail views of its associations, groups, and layers, and flower portraits of all the constituent species. Such a series can be obtained only by residence through a long term of years, and in most cases, general and aspect views, with portraits of the facies and a few of the striking principal species, must suffice. For views, a 6½ x 8½ inch camera is most satisfactory, while a 4 x 5 is large enough for detail and for individual plants. Quadrat and transect charts are of the greatest value for indicating the minute structure of formations, but the cost of reproduction has proved prohibitive to their use in the Colorado collection.

As in all formational work, it is difficult to give proper value to the fungi and algae of the various formations. After much deliberation, the writer has decided to treat these, so far as Colorado formations are concerned, in a supplementary collection under the title, "Cryptogamae Formationum Coloradensium." This will include the mosses and liverworts as well, the ferns having been treated in the original collection. The plan is to arrange all the cryptogams of each formation in their proper order, grouping them into layers and aspects in so far as possible, and making use of the camera for the detail of groups and the portraits of important species.

The arrangement of species within each formation herbarium is based upon gross structure when layers and zones are present, and also upon time of appearance and abundance. In the Colorado collection, the first division is into three aspects based upon the period of flowering (*aspectus vernalis, aestivalis, autumnalis*). Within each aspect, the species are arranged with respect to abundance in the groups, facies, principal species, and secondary species. Each group is placed in a manila cover, bearing a

printed label indicating the aspect and group. The species labels give, in addition to the name, date, and place of collection, the vegetation form, the geographical area, the rank of the species, the aspect, and the formation. The labels are printed in Latin, and the whole nomenclature is of necessity in this international language. The terms used are those proposed by the writer in "A System of Nomenclature for Phytogeography."

The arrangement of formation herbaria may follow the classification of formations with respect to character, region, or development. The first is certainly the most convenient for purposes of instruction, and has distinct advantages in permitting a close comparison of the vegetation of different habitats. The second arrangement, which is the one followed in the "Herbaria Formationum Coloradensium," is peculiarly adapted to mountain vegetation, in which the zones are usually very distinct. The arrangement of herbaria in a developmental series, however, is at the same time the most logical and the most illuminating, as the structure of the ultimate formations is not only made plain, but the stages in their development are also laid bare. Such succession herbaria are the natural outgrowth of formational ones. The latter, indeed, should simply be made the starting point for the former in all regions where the causes which bring about successions are active. Where weathering is still an important factor, as in mountains, the initial and intermediate formations which lead to the final grassland or forest are often in evidence, and the group of formation herbaria may be changed into a succession herbarium simply by arranging them in the sequence of the developmental stages. Thus, in the Colorado collection, the subalpine formations are arranged according to altitude in the following series: (1) the pine formation, (2) the gravel slide formation, (3) the half gravel slide formation, (4) the aspen formation, (5) the balsam-spruce formation, (6) the spruce-pine formation, (7) the meadow thicket formation, (8) the brook bank formation. Of these, five belong to the same succession, and it is possible to trace the development of the spruce-pine forest by arranging these five formations in their proper order in a succession her-

barium, as follows: (1) the gravel slide formation, (2) the half gravel slide formation, (3) the pine formation, (4) the balsam-spruce formation, (5) the spruce-pine formation.

The value of formation herbaria in the exposition of a vegetative covering and the methods of arrangement and classification to be employed are illustrated by the following descriptive list of the Colorado formations:

## HERBARIA FORMATIONUM COLORADENSIUM

### PAGOPHYTIA: FOOTHILL FORMATIONS

#### Bouteloua-Andropogon-psilium
The plains grass formation

ASPECTUS AESTIVALIS

*Facies*

1. Bouteloua hirsuta Lag.
2. Atheropogon curtipendulus (Michx.) Fourn.

*Species principales*

3. Talinum parviflorum Nutt.
3.1. Plantago purshii R. & S.
4. Pentstemon unilateralis Rydb.
5. Argemone intermedia Sweet
6. Cleome serrulata Pursh
7. Munroa squarrosa (Nutt.) Torr.
8. Helianthus petiolaris Nutt.
9. Verbena bracteosa Michx.

*Species secondariae*

10. Anogra pallida (Lindl.) Britt.
11. Anogra coronopifolia (T. & G.) Britt.
12. Euphorbia cuphosperma (Engelm.) Boiss.
13. Gilia aggregata (Pursh) Spreng.
14. Asclepias pumila (Gray) Vail

ASPECTUS AUTUMNALIS

*Facies*

15. Andropogon scoparius Michx.
16. Andropogon furcatus Muhl.
17. Stipa vaseyi Scribn.

*Species principales*

18. Senecio spartioides Torr. & Gr.
19. Gutierrezia sarothrae (Pursh) Britt. & Rusby
20. Artemisia frigida Willd.
21. Eriogonum effusum Nutt.
22. Eriogonum annuum Nutt.

*Species secondariae*

23. Sphaeralcea cuspidata (Gray) Britt.
24. Salvia lanceolata Willd.
25. Euphorbia serpyllifolia Pers.
26. Muhlenbergia gracillima Torr.
27. Eriocoma cuspidata Nutt.
28. Psoralea tenuiflora Pursh
29. Ambrosia psilostachya DC.

QUERCUS-CERCOCARPUS-LOCHMODIUM

The foothill thicket formation

*Facies*

30. Quercus novimexicana (DC.) Rydb.
31. Cercocarpus parvifolia Nutt.
32. Rhus trilobata Nutt.
33. Prunus demissa (Nutt.) Walp.

ASPECTUS AESTIVALIS

*Species principales*

34. Tetraneuris glabriuscula Rydb.
35. Malvastrum coccineum (Pursh) Gray
36. Allionia hirsuta Pursh
37. Mentzelia nuda (Pursh) Torr. & Gr.
38. Thelesperma gracile (Torr.) Gray
39. Chrysopsis villosa (Pursh) Nutt.

40. Aristida longiseta Steud.
41. Helianthus pumilus Nutt.
42. Kuhniastera oligophylla (Torr.) Heller
43. Kuhniastera purpurea (Vent.) MacM.
44. Froelichia gracilis Moq.
45. Gaura coccinea Pursh
46. Lycurus phalarioides H.B.K.
47. Castilleia integra Gray
47.1. Phacelia glandulosa Nutt.
47.2. Delphinium ramosum Rydb.
47.3. Asclepias tuberosa L.

*Species secondariae*

48. Hedeoma nana (Torr.) Greene
49. Polygonum douglasii Greene
50. Bromus porteri lanatipes Shear
51. Onagra strigosa Rydb.
52. Erigeron beyrichii (F. & M.) Torr. & Gr.
53. Eriogonum alatum Torr.
54. Phacelia heterophylla Pursh
54.1. Comandra pallida A. DC.
54.2. Astragalus sparsiflorus Gray

ASPECTUS AUTUMNALIS

*Species principales*

55. Verbesina encelioides (Cav.) Gray
56. Machaeranthera cichoriacea Greene
57. Artemisia ludoviciana Nutt.
58. Machaeranthera viscosa Nutt.
59. Gymnolomia multiflora Benth. & Hook.
60. Mirabilis oxybaphoides Gray
61. Sideranthus spinulosum (Pursh) Sweet
62. Solidago pallida Porter

*Species secondariae*

63. Eurotia lanata (Pursh) Moq.
64. Bidens bigelovii Gray
65. Bidens tenuisecta Gray

66. Kuhnia gooddingii A. Nels.
67. Aster polycephalus Rydb.
68. Gentiana affinis Griseb.
69. Eupatorium texense (T. & G.) Rydb.
70. Artemisia gnaphalodes Nutt.
71. Clematis ligusticifolia Nutt.
72. Laciniaria punctata (Hook.) OK.
73. Melica parviflora (Porter) Scribn.
73.1. Cheilanthes fendleri Hook.
73.2. Notholaena fendleri Kunze
73.3. Woodsia plummerae Lemmon
73.4. Woodsia mexicana Fee

PINUS-JUNIPERUS-XEROHYLIUM

The foothill woodland formation

*Facies*

74. Pinus edulis Engelm.
75. Juniperus monosperma (Engelm.) Sarg.

*Species principales*

76. Stipa scribneri Vasey

*Species secondariae*

77. Cheilanthes feei Moore
78. Coleanthus albicaule Rydb.
79. Pericome caudata Gray

## OREOPHYTIA: SUBALPINE FORMATIONS

PINUS PONDEROSA-FLEXILIS-XEROHYLIUM

The pine formation

*Facies*

80. Pinus ponderosa Dougl.
81. Pinus flexilis James

ASPECTUS VERNALIS

*Species principales*

82. Arctostaphylus uva-ursi (L.) Spreng.
83. Pentstemon secundiflorus Benth.
84. Pentstemon humilis Nutt.

*Species secondariae*

85. Pulsatilla hirsutissima (Pursh) Britt.
86. Draba streptocarpa Gray
87. Pentstemon humilis roseiflora
88. Erysimum elegans Rydb.
89. Erigeron multifidus Rydb.

ASPECTUS AESTIVALIS

*Species principales*

90. Geranium caespitosum James
91. Drymocallis fissa (Nutt.) Rydb.

*Species secondariae*

92. Arenaria fendleri Gray

ASPECTUS AUTUMNALIS

*Species principales*

93. Gentiana affinis Griseb.

PSEUDOCYMOPTERUS-MENTZELIA-CHALICODIUM
The gravel slide formation

ASPECTUS VERNALIS

*Facies*

94. Pseudocymopterus anisatus (Gray) C. & R.
95. Scutellaria brittonii Porter

*Species principales*

96. Vagnera stellata (L.) Morong
97. Physaria acutifolia Rydb.
98. Aragallus multiceps (Nutt.) Heller
99. Atragene occidentalis chalicodocolus

*Species secondariae*

100. Pentstemon torreyi Gray

ASPECTUS AESTIVALIS

*Facies*

101. Touterea multiflora (Nutt.) Rydb.
102. Oreocarya virgata (Porter) Greene
103. Paronychia jamesii Torr. & Gr.

*Species principales*

104. Rubus strigosus Michx.
105. Gilia pinnatifida Nutt.
106. Pachylophus caespitosus (Nutt.) Raimann
107. Apocynum androsaemifolium L.
108. Pentstemon brandegei Porter
109. Senecio rosulatus Rydb.

*Species secondariae*

110. Capnoides aureum (Willd.) OK.
111. Bromus pumpellianus Scribn.
112. Allionia linearis Pursh
113. Pentstemon brandegei prostratus
114. Polygonum convolvulus L.
115. Arenaria saxosa Gray

ASPECTUS AUTUMNALIS

*Facies*

116. Machaeranthera aspera Greene

*Species principales*

117. Eriogonum flavum Nutt.
118. Coleanthus congestum A. Nels.

ELYMUS-MUHLENBERGIA-CHALICODIUM
The half gravel slide formation

*Facies*

119. Elymus ambiguus Vas. & Scribn.
120. Muhlenbergia gracilis Trin.
121. Blepharoneurum tricholepis (Torr.) Nash
122. Opulaster monogyna (Torr.) OK.
122.1. Yucca glauca Nutt.

ASPECTUS VERNALIS

*Species principales*

123. Rubus deliciosus James
124. Mertensia linearis Greene

*Species secondariae*

125. Euphorbia robusta (Engelm.) Small
126. Erigeron glandulosus Porter
126.1. Arabis holboellii fendleri Wats.
126.2. Bursa bursa-pastoris nana

ASPECTUS AESTIVALIS

*Species principales*

127. Holodiscus dumosa (Nutt.) Heller
128. Gilia aggregata (Pursh) Spreng.
129. Sedum stenopetalum Pursh
130. Campanula petiolata DC.
131. Erigeron speciosus DC.
132. Allium recurvatum Rydb.
133. Galium boreale L.
134. Lappula texana (Scheele) Britt.
135. Koelera cristata (L.) Pers.
136. Silene hallii Wats.
137. Heuchera hallii Gray
138. Epilobium paniculatum Nutt.

*Species secondariae*

139. Monarda menthifolia Benth.
140. Agoseris greenei (Gray) Rydb.
141. Potentilla propinqua Rydb.
142. Potentilla bipinnatifida Dougl.
143. Chrysopsis amplifolia Rydb.
144. Orthocarpus luteus Nutt.
145. Antennaria umbrinella Rydb.
146. Draba aureiformis Rydb.
147. Potentilla monspeliensis L.
148. Solanum triflorum Nutt.
149. Poa crocata Michx.

ASPECTUS AUTUMNALI

*Species principales*

150. Muhlenbergia subalpina Vasey
151. Solidago extraria (Gray)
152. Senecio eremophilus Richards
153. Leptilum canadense chalicodocolum
154. Psoralea tenuiflora Pursh
155. Aster porteri Gray
156. Artemisia scouleriana (Bess.) Rydb.
157. Muhlenbergia racemosa (Michx.) B.S.P.

*Species secondariae*

158. Artemisia rhizomata A. Nels.
159. Bahia dissecta (Gray) Britt.
160. Boebera papposa (Vent.) Rydb.
161. Eriogonum cernuum Nutt.
162. Sporobolus confusus Vasey

POPULUS TREMULOIDES-HYLIUM

The aspen formation

*Facies*

163. Populus tremuloides Michx.

ASPECTUS VERNALIS

*Species principales*

164. Rosa sayii Schwein.
165. Fragaria glauca (Wats.) Rydb.
166. Carex pennsilvanica Lam.
167. Pedicularis canadensis L.
168. Sieversia ciliata (Pursh) Rydb.
169. Poa longipeduncula Scribn.
170. Iris missouriensis Nutt.
171. Poa crocata Michx.

*Species secondariae*

172. Poa pratensis L.
173. Avena striata Michx.
174. Antennaria viscidula (A. Nels.) Rydb.

175. Anemone globosa Nutt.
176. Arabis oxyphylla Greene

ASPECTUS AESTIVALIS

Lamina herbacea superior

*Species principales*

177. Bromus richardsonii Link
178. Festuca thurberi Vasey
179. Agropyrum violaceum (Horn.) Vasey
180. Agropyrum richardsonii Schrad.
181. Danthonia parryi Scribn.
182. Avena americana Scribn.
183. Koelera cristata (L.) Pers.
184. Pedicularis procera Gray
185. Antennaria anaphaloides Rydb.
186. Valeriana purpurascens A. Nels.
187. Helianthella parryi Gray
188. Achillea lanulosa Nutt.
189. Delphinium ramosum Rydb.
190. Pentstemon glaucus Graham
191. Erigeron subtrinervis Rydb.

*Species secondariae*

192. Frasera speciosa Dougl.
193. Rudbeckia flava Moore
194. Lithospermum multiflorum Torr.
195. Anemone globosa rubriflora
196. Zygadenus elegans Pursh

Lamina herbacea inferior

*Species principales*

197. Erigeron visciduus Rydb.
198. Carex obtusata Lilj.
199. Carex filifolia Nutt.
200. Festuca pseudovina Hackel
201. Sisyrinchium angustifolium Miller
202. Antennaria microphylla Rydb.

203. Campanula petiolata DC.
204. Calochortus gunnisonii Wat
205. Solidago extraria (Gray)

*Species secondariae*

206. Erigeron flagellaris Gray
207. Antennaria imbricata E. Nels.
208. Antennaria concinna E. Nels.

ASPECTUS AUTUMNALIS

*Species principales*

209. Castilleia confusa Greene
210. Gentiana parryi Engelm.
211. Gentiana acuta Michx.
212. Agoseris glauca (Pursh) Greene

*Species secondariae*

213. Solidago oreophila Rydb.
214. Gentiana barbellata Engelm.

PICEA-PSEUDOTSUGA-HYLIUM

The balsam-spruce formation

*Facies*

215. Picea engelmannii Parry
216. Pseudotsuga mucronata (Raf.) Sudw.
217. Picea parryana Sarg.

ASPECTUS VERNALIS

*Species principales*

218. Acer glabrum Torr.
219. Betula occidentalis Hook.
220. Cornus amomum Mill.
221. Prunus pennsilvanica L.
222. Opulaster intermedia Rydb.
223. Ribes molle (Gray) Howell
224. Edwinia americana (T. & G.) Heller
224.5. Juniperus communis L.
225. Rosa sayii Schwein.

226. Viburnum pauciflorum Pylaie
227. Atragene occidentalis Hornem.
228. Fragaria pauciflora Rydb.
229. Heuchera parvifolia Nutt.
230. Aralia nudicaulis L.
231. Fragaria bracteata Heller
232. Mertensia pratensis Heller
233. Synthyris plantaginea Benth.
234. Viola biflora L.

*Species secondariae*

235. Pseudocymopterus tenuifolius (Gray)
236. Washingtonia obtusa Coult. & Rose
237. Corallorrhiza multiflora Nutt.
238. Pirola chlorantha Sw.
239. Actaea rubra (Ait.) Willd.
240. Limnorchis stricta (Lindl.) Rydb.
241. Valeriana ovata Rydb.
242. Vagnera leptopetala Rydb.
242.1. Viola blanda L.
242.2. Corallorhiza corallorhiza (L.) Karst.

ASPECTUS AESTIVALIS

*Species principales*

243. Thalictrum sparsiflorum Turcz.
244. Streptopus amplexifolius (L.) DC.
245. Saxifraga austromontana Wiegand
246. Erigeron salsuginosus (Rich.) Gray
247. Erigeron superbus Greene
248. Galium boreale hylocolum
249. Castilleia confusa Greene
250. Galium triflorum Michx.
251. Pirola asarifolia Michx.
252. Heracleum lanatum Michx.
253. Gentiana acuta Michx.

*Species secondariae*

254. Blitum capitatum L.
255. Allium recurvatum Rydb.
256. Alsine longipes (Goldie) Coville
257. Capnoides aureum (Willd.) OK.
258. Pirola secunda L.
259. Peramium ophioides (Fern.) Rydb.
260. Potentilla coloradensis Rydb.
261. Trisetum subspicatum (L.) Beauv.
262. Solidago oreophila Rydb.
263. Androsace diffusa Small
264. Aquilegia coerulea James
265. Campanula petiolata DC.
266. Zygadenus elegans Pursh

ASPECTUS AUTUMNALIS

*Species principales*

267. Cystopteris fragilis (L.) Bernh.
268. Senecio pudicus Greene
269. Solidago parryi (Gray) Greene
270. Peltigera aphthosa (L.) Hoffm.
271. Peltigera venosa (L.) Hoffm.
272. Cladonia furcata racemosa Fl.
273. Cladonia
274. Cladonia pyxidata (L.) Fr.
275. Cladonia fimbriata tubiformis Fr.
276. Cetraria
277. Psoroma hypnorum (Hoffm.) Koerb.
278. Lecidea viridescens (Schrad.) Ach.
279. Selaginella underwoodii Hieron.

*Species secondariae*

280. Asplenium filix-foemina (L.) Bernh.
281. Chenopodium fremontii Wats.

PICEA-PINUS-HYLIUM
The spruce-pine formation

*Facies*

(Picea engelmannii Parry)
282. Pinus aristata Engelm.

ASPECTUS PRIOR

*Species principales*

283. Salix nuttallii Sarg.
284. Polemonium pulchellum Bunge
285. Pirola minor L.
286. Thlaspi coloradense hylocolum
287. Adoxa moschatellina L.
288. Mertensia polyphylla Greene
289. Arenaria fendleri Gray
290. Fragaria pumila Rydb.

*Species secondariae*

291. Alsine baicalensis Coville
292. Androsace subumbellata (A. Nels.) Small
293. Arnica cordifolia Hook.
294. Moneses uniflora (L.) Gray
295. Draba streptocarpa Gray
296. Draba aurea Vahl.
297. Poa crocata Michx.
298. Pseudocymopterus montanus C. & R.
298.1. Senecio wernerifolius Gray
298.2. Ranunculus ovalis Raf.

ASPECTUS SEROTINUS

*Species principales*

299. Sedum stenopetalum Pursh
300. Solidago decumbens Greene
301. Erigeron salsuginosus Gray
302. Erigeron elatior (Hook.) Greene
303. Gentiana frigida Haenke

304. Poa crocata Michx.
305. Festuca pseudovina Hackel

*Species secondariae*

306. Carex bella Bailey
306.5. Bromus richardsonii Link
307. Erigeron debilis (Gray) Rydb.

SALIX-BETULA-HELOLOCHMIUM
The meadow thicket formation

*Facies*

308. Salix pseudolapponum Seemen
309. Salix chlorophylla Anders.
310. Salix chlorophylla Anders. var.
311. Salix geyerana Anders.
312. Salix glaucops Anders.
313. Salix bebbiana Sarg.
314. Salix monticola Bebb
315. Betula glandulosa Michx.
316. Dasyphora fruticosa (L.) Rydb.

ASPECTUS VERNALIS

*Species principales*

317. Sambucus microbotrya Rydb.
318. Elephantella groenlandica (Retz.) Rydb.
319. Thalictrum alpinum L.
320. Veronica wormskjoldii R. & S.
321. Juncoides comosum (Meyer) Kuntze
322. Carex aurea Nutt.
323. Geranium richardsonii F. & M.
324. Mertensia lateriflora Greene

*Species secondariae*

325. Ranunculus inamoenus Greene
326. Halerpestes cymbalaria (Pursh) Greene

ASPECTUS AESTIVALIS

*Species principales*

327. Deschampsia caespitosa (L.) Beauv.
328. Valeriana acutiloba Rydb.
329. Carex utriculata minor Boott
330. Sieversia turbinata helolochmocolus
331. Clementsia rhodantha (Gray) Rose
332. Castilleia sulphurea Rydb.
333. Carex alpina Swartz
334. Swertia scopulina Greene
335. Chamaenerium angustifolium (L.) Scop.
336. Danthonia intermedia Vasey
337. Phleum alpinum L.
338. Phleum pratense L.
339. Agrostis hiemalis (Walt.) B. S. P.
340. Eriophorum gracile Koch
341. Juncus balticus montanus Engelm.
342. Crepis runcinata (James) T. & G.
343. Potentilla pulcherrima Lehm.
344. Carex acutina tenuior Bailey
345. Senecio chloranthus Gray
346. Aster frondosus (Gray) Greene

*Species secondariae*

347. Calochortus gunnisonii Wats.
348. Lilium montanum A. Nels.
349. Eleocharis palustris glaucescens (Willd.) Gray
350. Scirpus pauciflorus Lightf.
351. Juncus castaneus Smith
352. Gyrostachys stricta Rydb.
353. Juncus longistylis Torr.
354. Erigeron minor (Hook.) Rydb.
355. Carex douglasii Boott
356. Thlaspi glaucum A. Nels.
357. Antennaria imbricata E. Nels.
358. Poa pratensis L.
359. Cerastium oreophilum Greene

360. Trifolium repens L.
361. Carex siccata Dewey
362. Carex canescens L.
363. Webera nutans Hedw.
363.1. Taraxacum dumetorum Greene

ASPECTUS AUTUMNALIS

*Species principales*

364. Aster geyeri (Gray) Howell
365. Gentiana acuta Michx.
366. Poa leptocoma Bong.
367. Mertensia ciliata Don
368. Nabalus racemosus (Michx.) DC.

*Species secondariae*

369. Saxifraga hirculus L.
370. Gnaphalium strictum Gray
371. Solidago pulcherrima A. Nels.

POLYGONUM-MERTENSIA-OCHTHIUM
The brook bank formation

ASPECTUS VERNALIS

*Species principales*

372. Rosa woodsii Lindl.
373. Juncoides parviflorum (Ehrb.) Coville
374. Dodecatheon pauciflorum (Dur.) Greene

ASPECTUS AESTIVALIS

*Facies*

375. Polygonum bistortoides Pursh
376. Mertensia polyphylla Greene

*Species principales*

377. Aconitum columbianum Nutt.
378. Calamagrostis canadensis (Michx.) Beauv.
379. Carex variabilis Bailey
380. Panicularia nervata (Willd.) OK.

381. Geum rivale L.
382. Carex tenella Schkuhr
383. Ligusticum porteri Coult. & Rose
384. Rudbeckia flava Moore
385. Mnium cuspidatum Hedw.

*Species secondariae*

386. Carduus scopulorum Greene
387. Poa pratensis L.
388. Epilobium adenocaulum Haussk.
389. Epilobium adenocaulum Haussk. var.
390. Geum oregonense (Scheutz) Rydb.
391. Arabis hirsuta (L.) Scop.
392. Saxifraga punctata L.
393. Achillea lanulosa ochthocolus
394. Solidago multiradiata Ait.
395. Rumex occidentalis Wats.
396. Agrostis alba L.
397. Poa serotina Ehr.
398. Apocynum androsaemifolium L.

ASPECTUS AUTUMNALIS

*Species principales*

399. Aster geyeri (Gray) Howell

*Species secondariae*

400. Solidago canadensis L.
401. Kuhnia gooddingii A. Nels.

## ACROPHYTIA: ALPINE FORMATIONS

### Carex-Campanula-coryphium
The alpine meadow formation

ASPECTUS PRIOR

*Facies*

402. Carex rupestris All.
403. Carex filifolia Nutt.
404. Sieversia turbinata (Rydb.) Greene

405. Mertensia alpina (Torr.) Don
406. Rydbergia grandiflora (T. & G.) Greene
407. Festuca brachyphylla nana

*Species principales*

408. Achillea lanulosa coryphocolus
409. Primula angustifolia Torr.
410. Salix saximontana Rydb.
411. Dryas octopetala L.
412. Castilleia occidentalis Torr.
413. Sibbaldia procumbens L.
414. Artemisia scopulorum Gray
415. Artemisia pattersonii Gray
416. Androsace chamaejasme Host.
417. Trifolium nanum Torr.
418. Eritrichium aretioides DC.
419. Potentilla rubricaulis Lehm.
420. Juncoides spicatum (L.) OK.
421. Campanula uniflora L.
422. Lloydia serotina Reichenb.
423. Carex chalciolepis Holm
424. Festuca pseudovina Hackel
425. Cerastium strictum L.
426. Allium reticulatum Don
427. Thlaspi coloradense Rydb.
428. Saxifraga flagellaris Willd.
429. Saxifraga chrysantha Gray
430. Saxifraga interrupta nana
431. Polemonium confertum Gray
431.1. Pseudocymopterus montanus purpureus C. & R.

*Species secondariae*

432. Pedicularis parryi Gray
433. Sedum frigidum Rydb.
434. Erigeron leucotrichus Rydb.
435. Oreoxis humilis Raf.
436. Carex festiva Dewey
437. Draba streptocarpa Gray

438. Draba aurea Vahl
439. Festuca ovina ingrata Hackel
440. Sieversia ciliata (Pursh) Rydb.
441. Erysimum caespitosum Rydb.
442. Saxifraga interrupta Greene
443. Chionophila jamesii Benth.
444. Danthonia intermedia coryphocolus
445. Castilleia
446. Androsace subumbellata (A. Nels.) Small

ASPECTUS SEROTINUS

*Facies*

447. Deschampsia caespitosa alpina Vasey
448. Polygonum viviparum L.
449. Campanula petiolata coryphocolus

*Species principales*

450. Phleum alpinum coryphocolum
451. Gentiana frigida coryphocolus
452. Poa pattersonii Vasey
453. Agrostis hiemalis coryphocolus
454. Trisetum subspicatum (L.) Beauv.
455. Gentiana acuta coryphocolus
456. Gentiana tenella Rottb.
457. Poa
458. Poa pratensis L. var.

*Species secondaria*

459. Erigeron leucotrichus Rydb.
460. Agoseris aurantiaca (Hook.) Greene
461. Solidago decumbens coryphocolus
462. Gentiana parryi coryphocolus
463. Blepharoneurum tricholepis coryphocolum
464. Alopecurus geniculatus fulvus (Smith) Scribn.
465. Poa grayana Vasey
466. Poa
467. Erigeron glabellus Nutt.

CAREX-SCIRPUS-HELIUM
The alpine bog formation

ASPECTUS PRIOR

*Facies*

468. Carex scopulorum Holm
469. Carex melanocephala Turcz.
470. Caltha leptosepala DC.

*Species principales*

471. Carex aurea Nutt.
472. Carex brunnescens (Pers.) Poir.
473. Carex acutina Bailey
474. Carex alpina Swartz
475. Carex variabilis Bailey

*Species secondariae*

476. Juncus subtriflorus (E. Mey.) Coville
477. Vaccinium myrtillus L.
478. Veronica wormskjoldii R. & S.

ASPECTUS SEROTINUS

*Facies*

479. Scirpus pauciflorus Lightf.
480. Polytrichum gracile Menz.

*Species principales*

481. Elephantella groenlandica coryphocolus
482. Antennaria nardina Greene
483. Swertia scopulina coryphocolus
484. Gentiana acuta coryphocolus
485. Senecio crocatus Rydb.
486. Carex capillaris L.
487. Ligusticum porteri coryphocolum

*Species secondariae*

488. Juncus triglumis L.
489. Juncus castaneus Smith

SPARGANIUM-POTAMOGETON-LIMNIUM
The alpine lake formation

*Facies*

490. Sparganium angustifolium Michx.
491. Potamogeton alpinus Balbis
491.1. Sparganium angustifolium ochthocolum

*Species principales*

492. Utricularia vulgaris L.
493. Callitriche bifida (L.) Morong
493.1. Isoetes lacustris paupercula Engelm.

PARONYCHIA-SILENE-CHALICODIUM
The alpine mat formation

ASPECTUS PRIOR

*Facies*

494. Paronychia pulvinata Gray
495. Silene acaulis L.
496. Arenaria sajanensis Willd.
497. Erigeron pinnatisectus (Gray) A. Nels.
498. Tetraneuris lanata (Nutt.) Greene

*Species principales*

499. Trifolium dasyphyllum Torr. & Gr.
500. Carex ebenea Rydb.
501. Carex petaseta Dewey
502. Zygadenus elegans Pursh
503. Polygonum bistortoides Pursh
504. Pentstemon hallii Gray
505. Agropyrum scribneri Vasey
506. Sieversia turbinata nana
507. Potentilla minutifolia Rydb.

*Species secondariae*

508. Saxifraga austromontana Wiegand
509. Phacelia lyallii (Gray) Rydb.
510. Pentstemon hallii nana
511. Aquilegia saximontana chalicodocolus
512. Polemonium pulchellum coryphocolum

513. Oreoxis alpina (Gray) Coult. & Rose
514. Festuca brachyphylla Schultes

ASPECTUS SEROTINUS

*Facies*

515. Senecio taraxacoides (Gray) Greene
516. Dasyphora fruticosa tenuifolia (Willd.) Rydb.

*Species principales*

517. Macronema pygmaeum (T. & G.) Greene
518. Trisetum subspicatum (L.) Beauv.
519. Calamagrostis purpurascens R. Br.

*Species secondariae*

520. Sedum stenopetalum Pursh
521. Arenaria verna aequicaulis A. Nels.
522. Senecio rosulatus coryphocolus

POLEMONIUM-SENECIO-PHELLIUM
The alpine rockfield formation

ASPECTUS PRIOR

*Facies*

523. Polemonium speciosum Rydb.
524. Primula parryi Gray
525. Claytonia megarrhiza (Gray) Parry

*Species principales*

526. Therophon jamesii (Torr.) Wheelock
527. Heuchera hallii Gray

*Species secondariae*

528. Aquilegia saximontana Rydb.
529. Synthyris plantaginea coryphocolus

ASPECTUS SEROTINUS

*Facies*

530. Senecio carthamioides Greene
531. Oxyria digyna (L.) Camptdera
532. Selaginella densa Rydb.

*Species principales*

533. Poa

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